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H2J JSAX J1NX J11VV
U1S S1966 S1967 S2003 S2006

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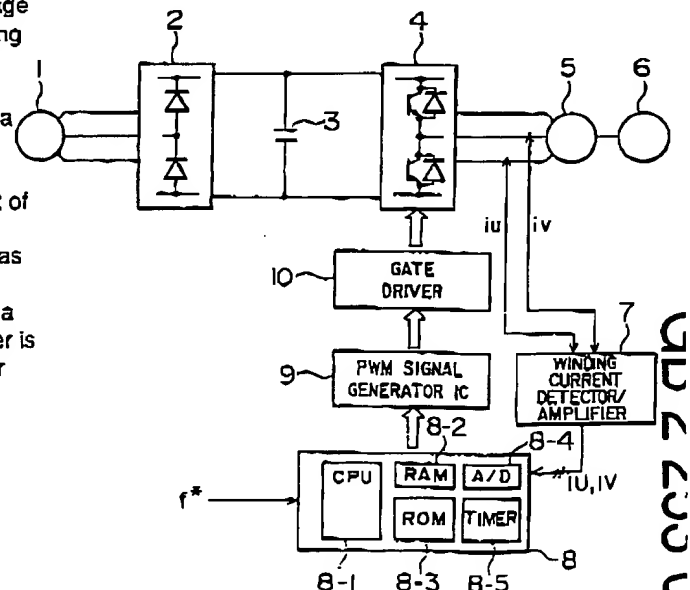
(58) Field of search

UK CL (Edition K) H2F FDUCT FDUCT FDUCT, H2J
JSAX JSVF JSVP JSVV
INT CL⁵ H02M, H02P

(54) Inverter control system

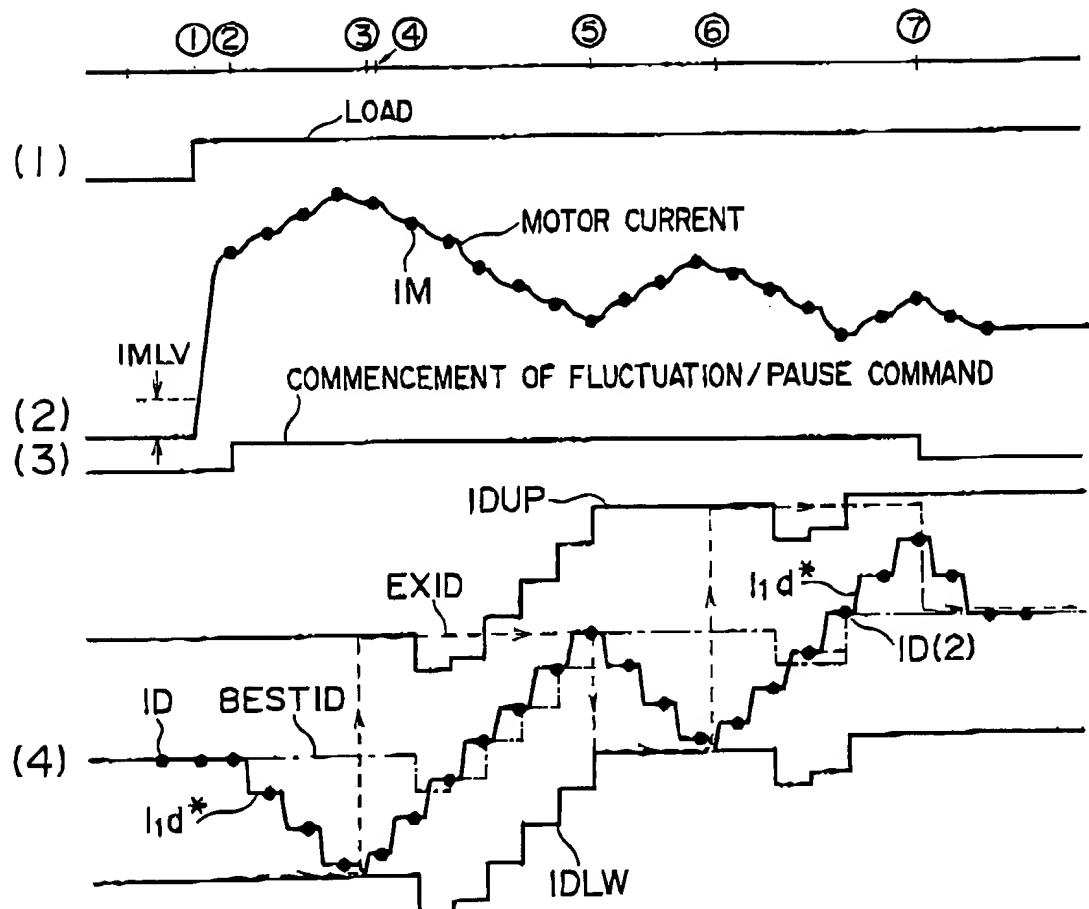
(57) An inverter control system is described which is immune to the influence of load disturbance and detection noise and permits stable minimization control of motor current, in order to attain high efficiency of an AC motor 5 and of an inverter 4 which drives the motor. A memory group (12, Fig. 6) in a control unit 8 is provided having a set of memories for storage of data representative of exciting current commands standing for manipulated variables derived from motor currents i_u , i_v and data representative of motor currents standing for controlled variables. Upper and lower limit values defining a fluctuation region of the exciting current command are so determined that an exciting current command data corresponding to a motor current data which is the smallest of all the current data in the memory group falls within the fluctuation region. The fluctuation region is so determined as to minimize the motor current while the exciting current command being fluctuated within the fluctuation region. In a further embodiment (Fig. 27) the input current to the inverter is used to feed a current detector 7 instead of using the motor load current. The motor may drive an airconditioner, refrigerator, a fan or a pump.

FIG. 5



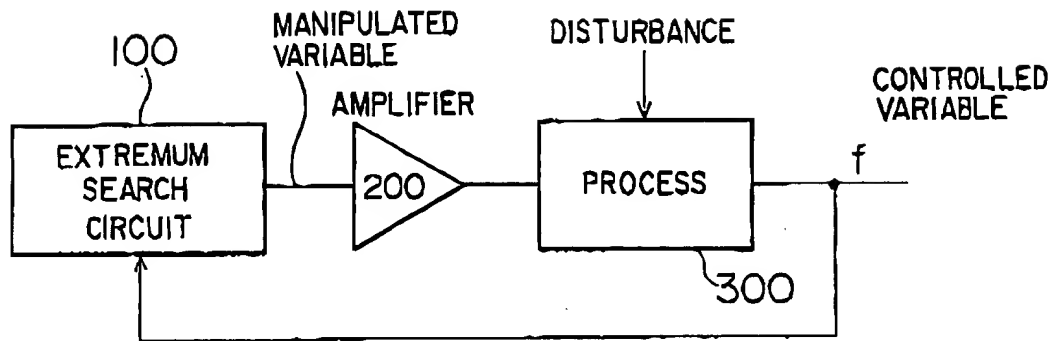
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FIG. 1

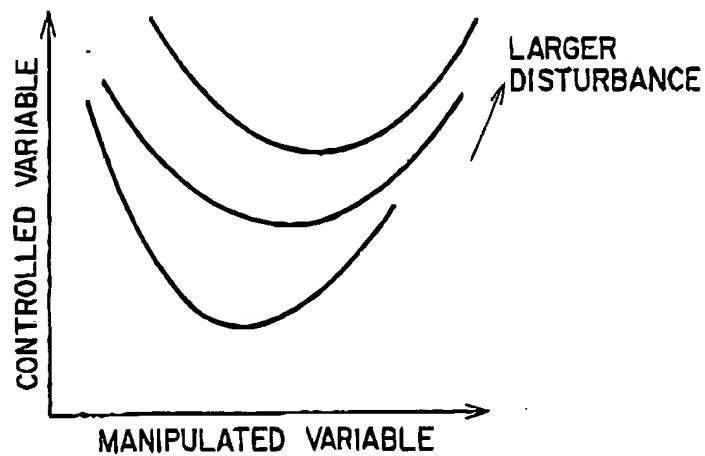


2/24

FIG. 2



(a)



(b)

3/24

FIG. 3

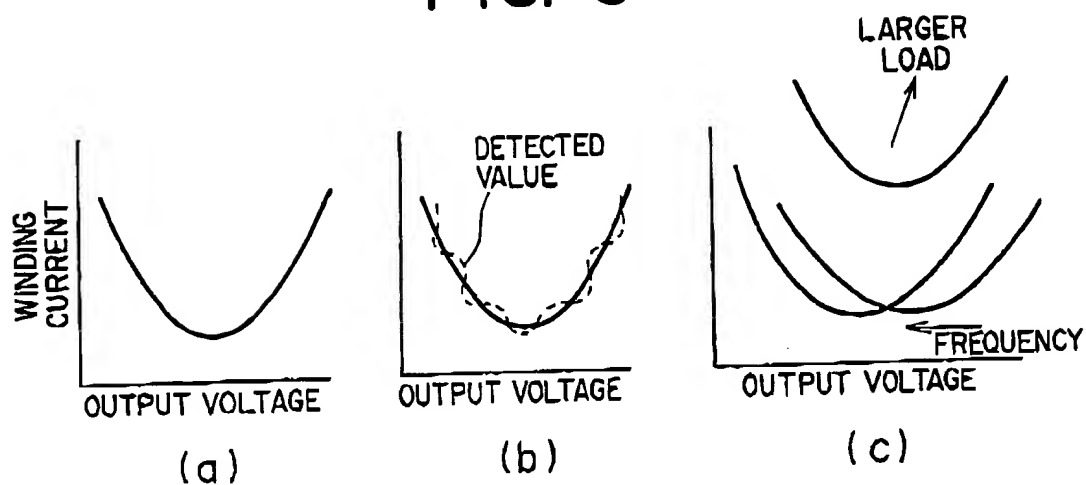
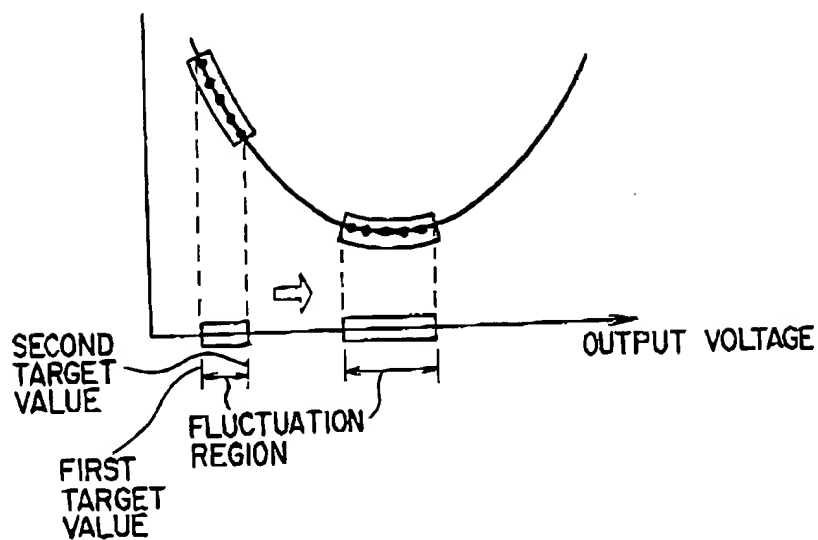
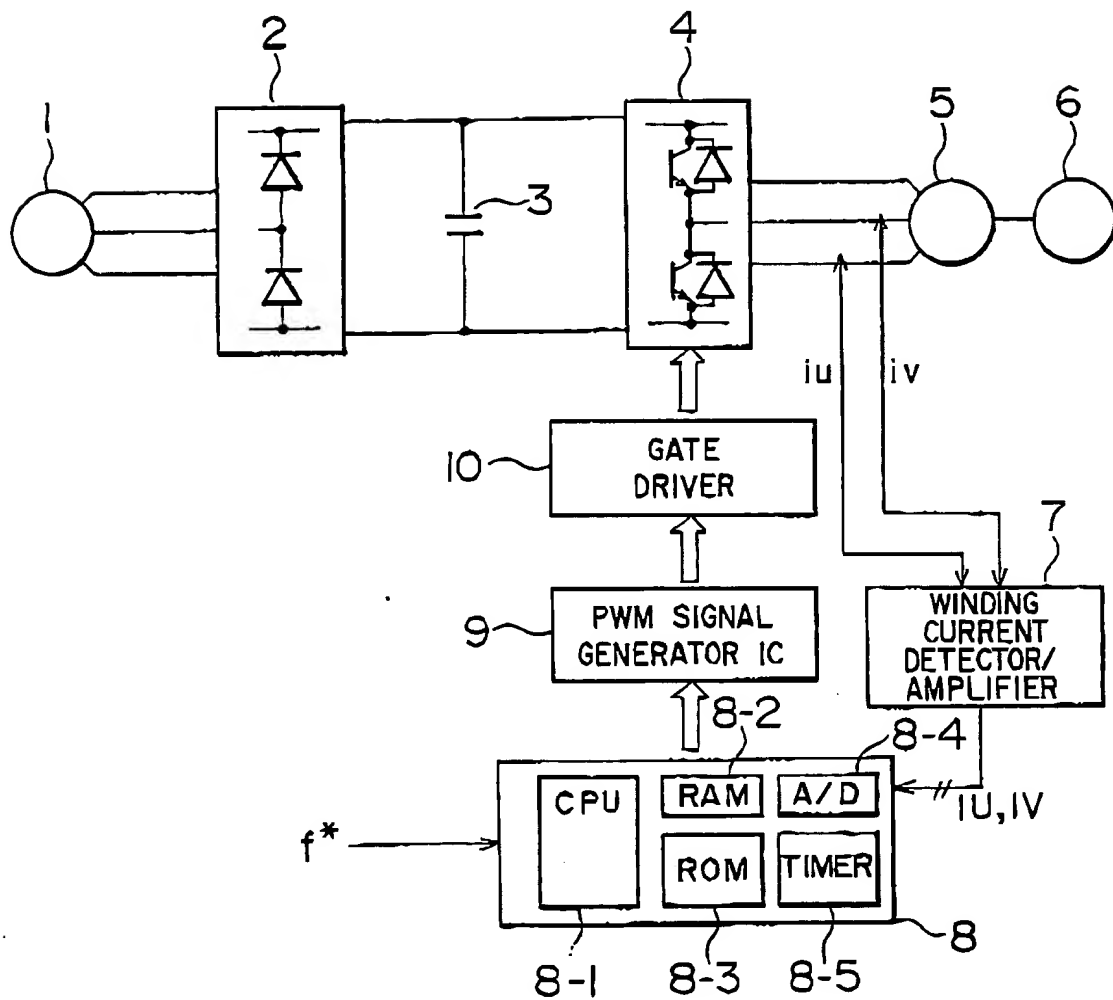


FIG. 4



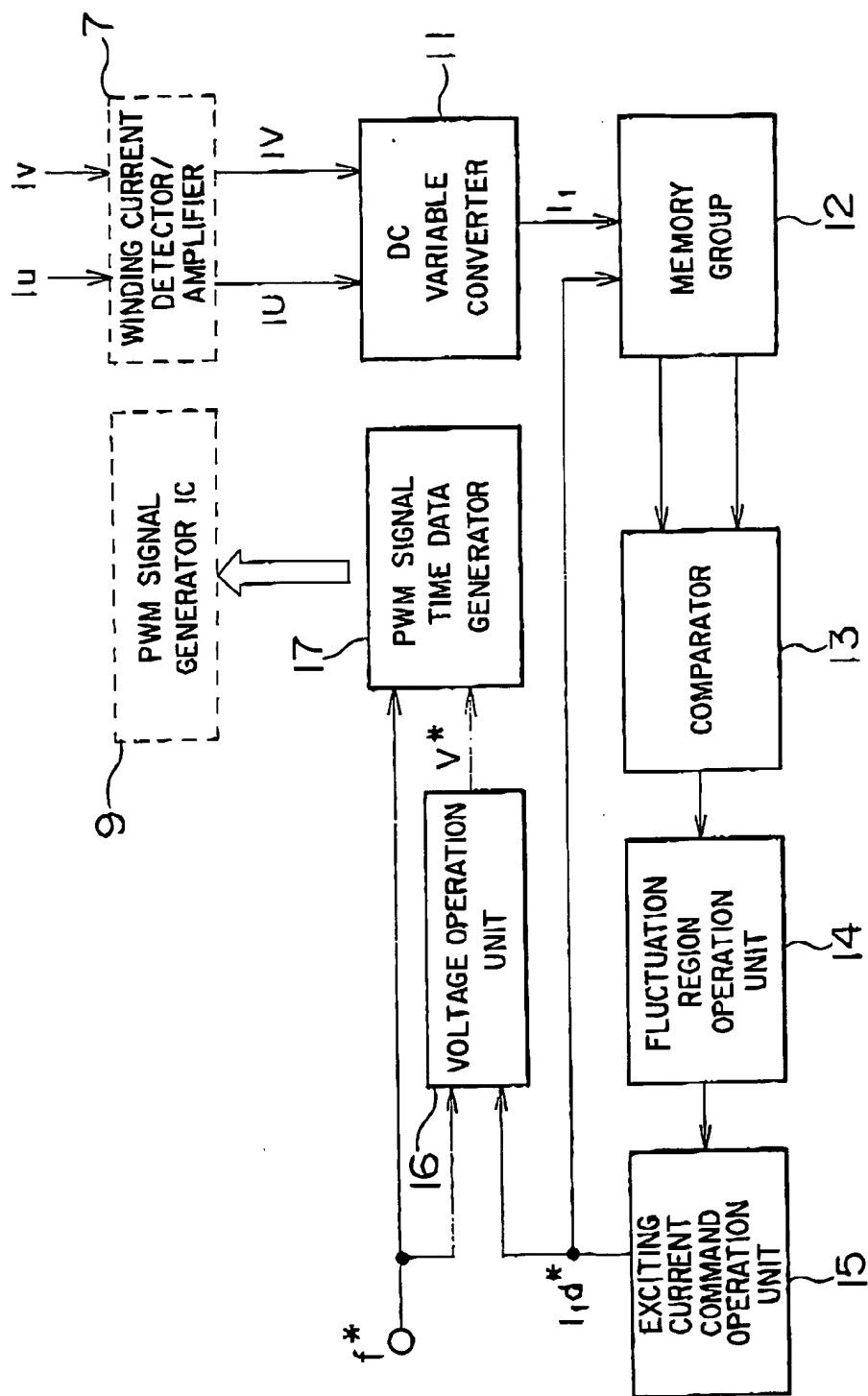
4/24

FIG. 5



5/24

FIG. 6



6.24

FIG. 7

DETECTION TIMING

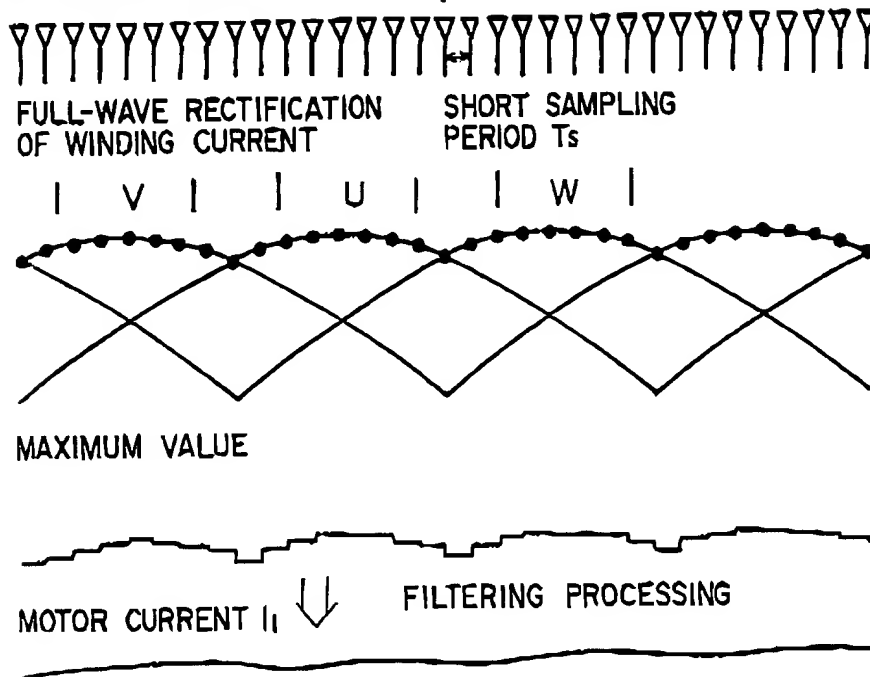
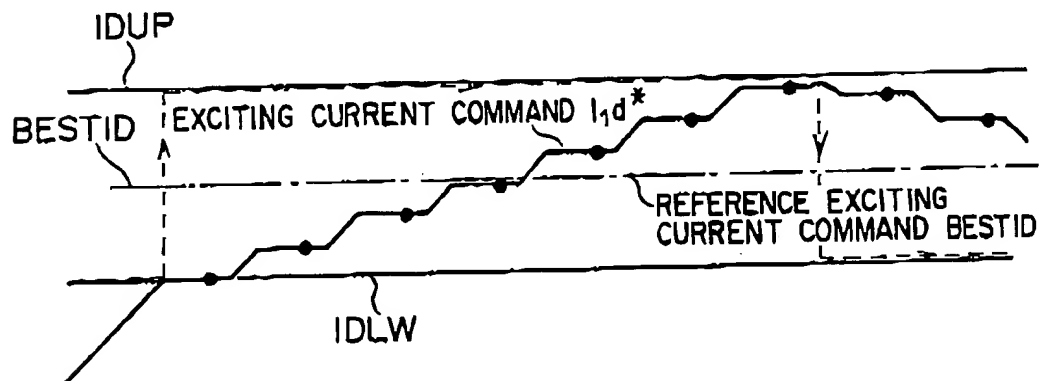
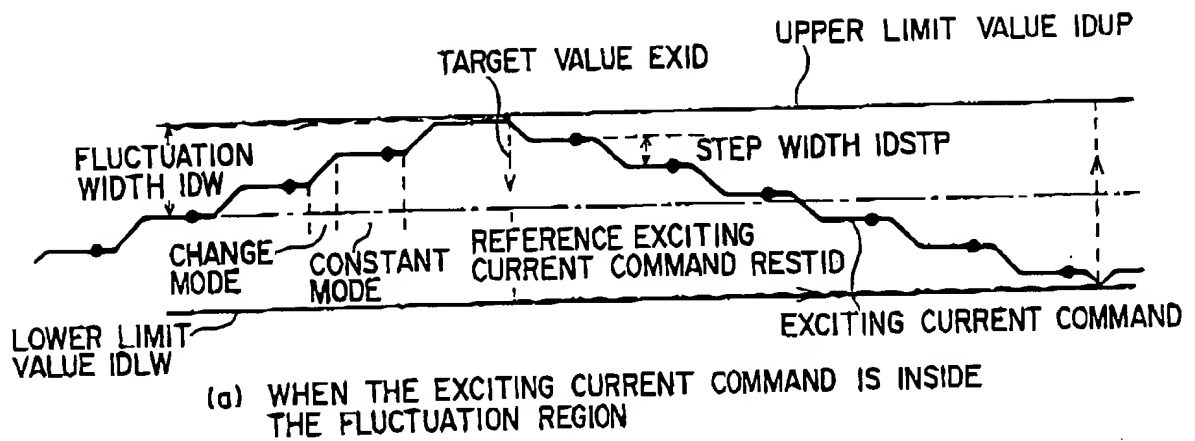


FIG. 8

0	MOTOR CURRENT	IM (0)	MEMORY GROUP 12
1	"	IM (1)	
2	"	IM (2)	
3	"	IM (3)	
4	"	IM (4)	
0	EXCITING CURRENT COMMAND	ID (0)	
1	"	ID (1)	
2	"	ID (2)	
3	"	ID (3)	
4	"	ID (4)	

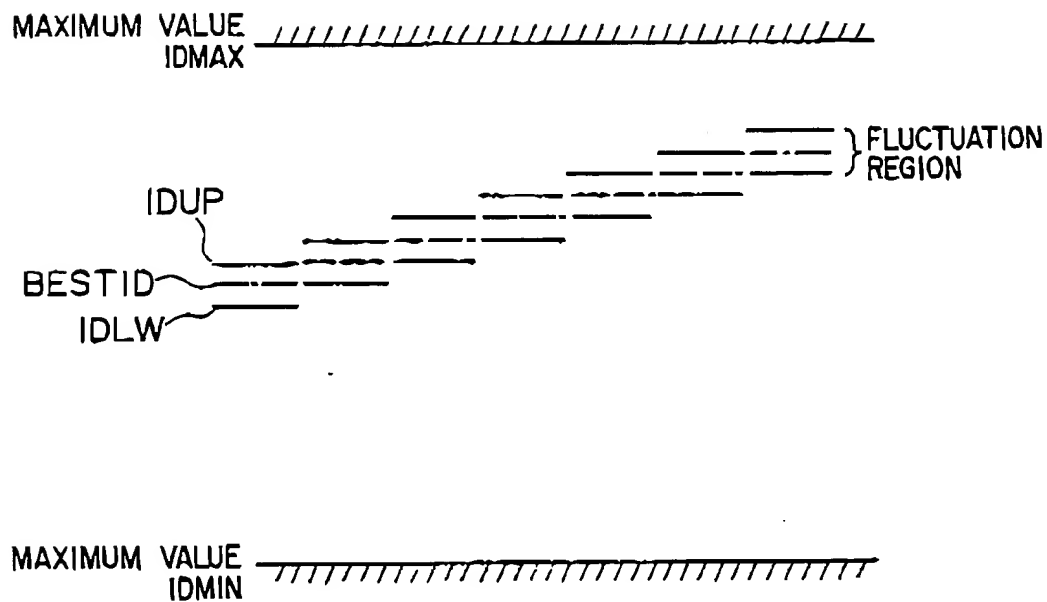
7/24

FIG. 9



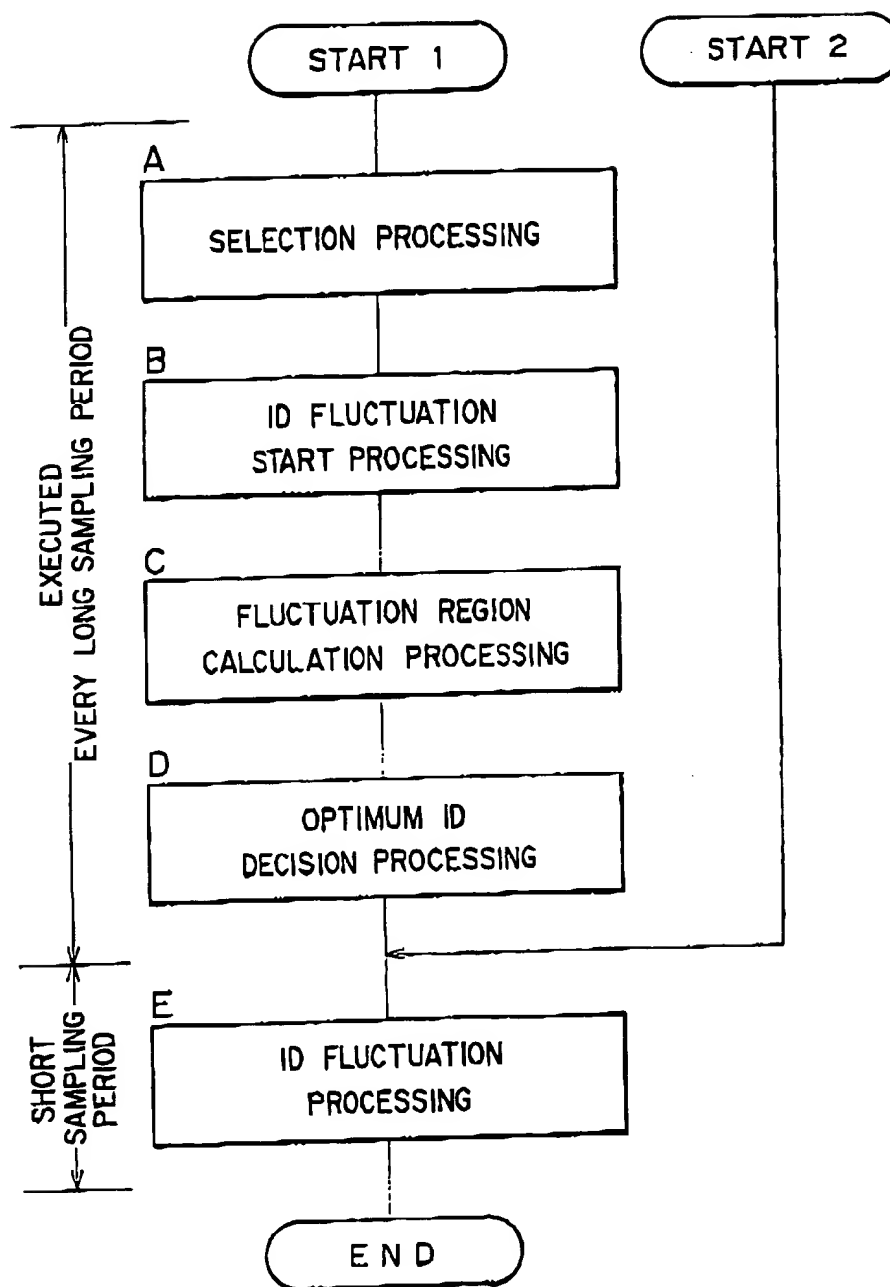
8/24

FIG. 10



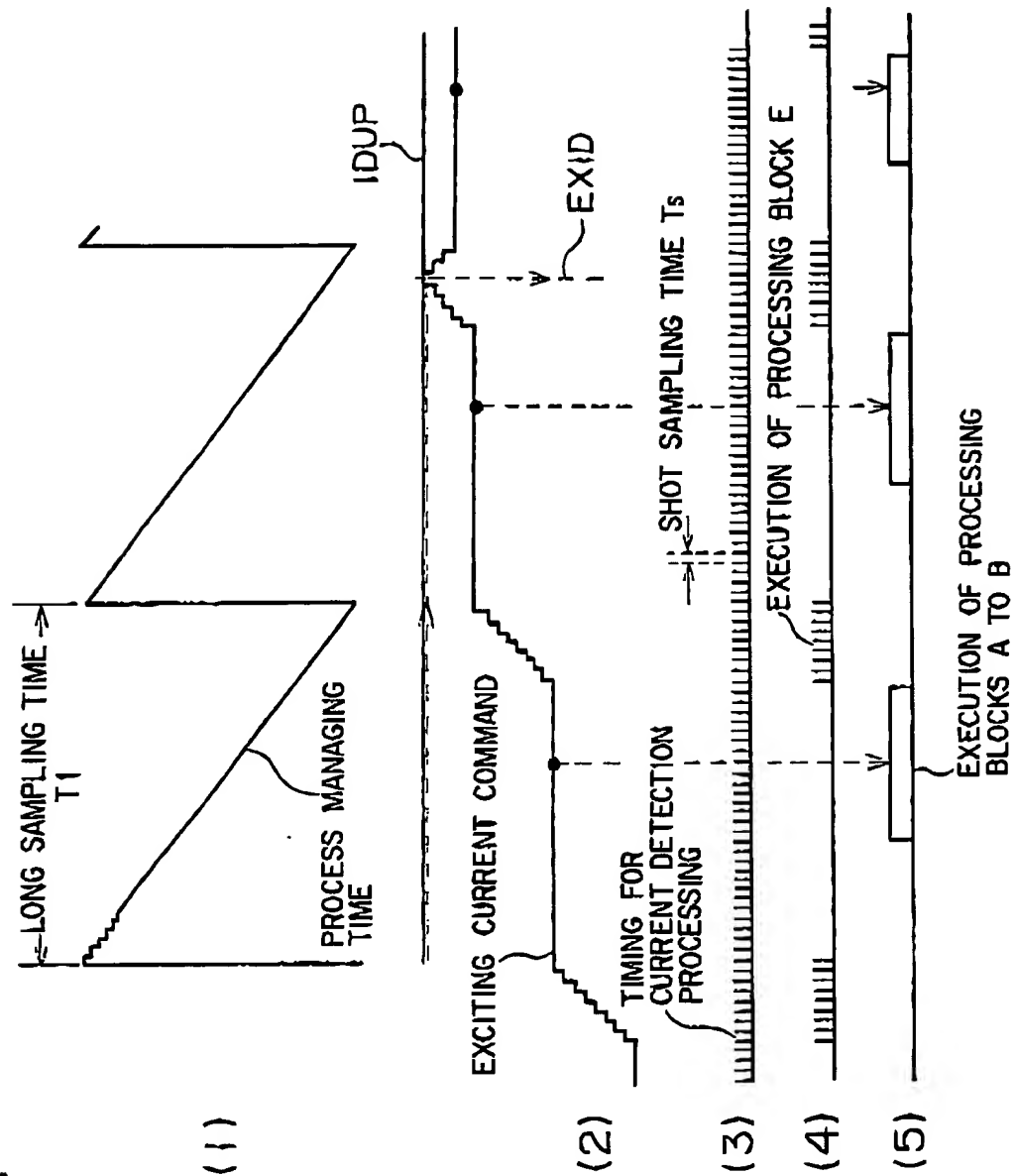
9/24

FIG. 11



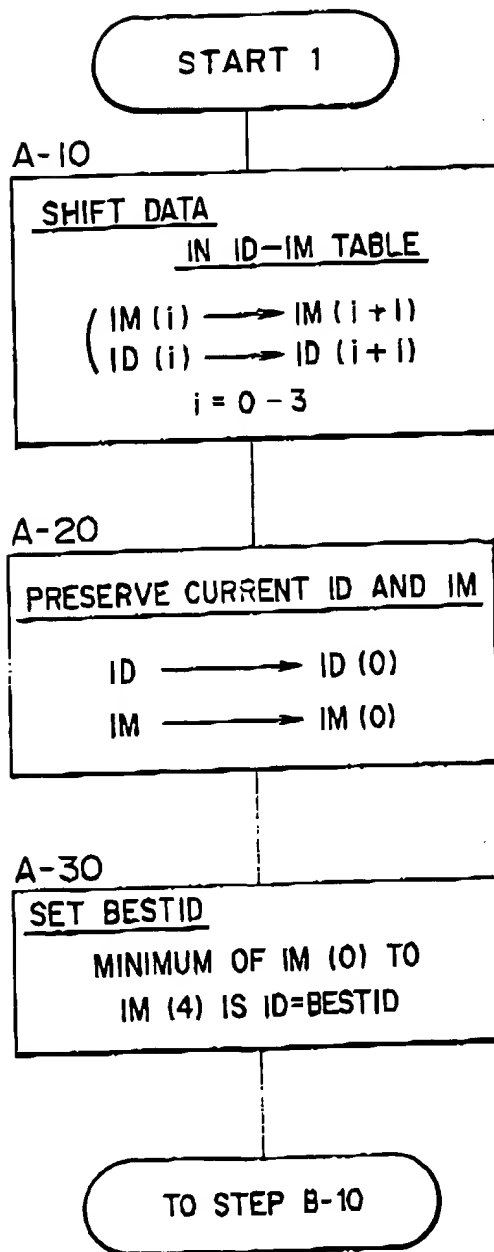
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FIG. 12



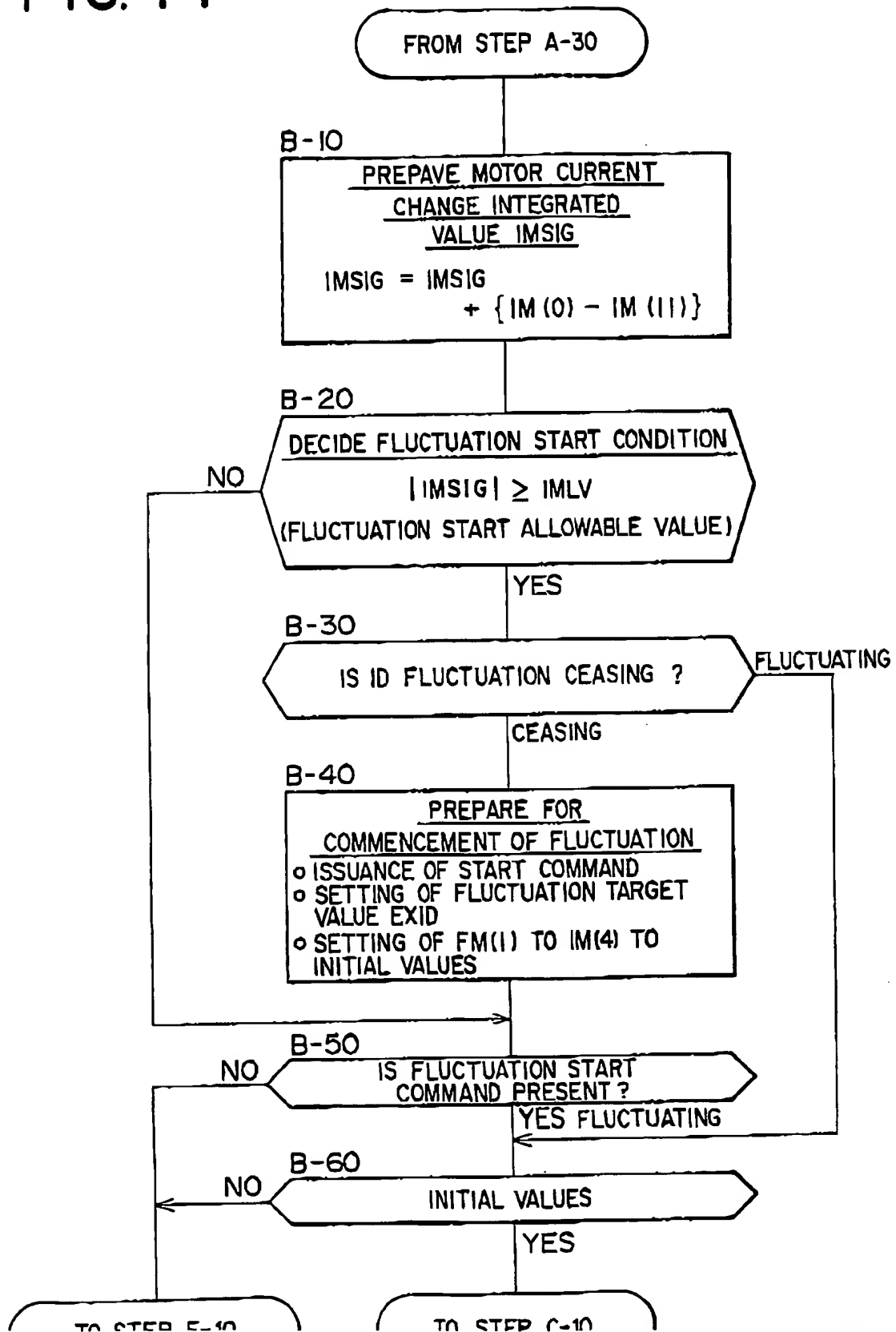
11/24

FIG. 13



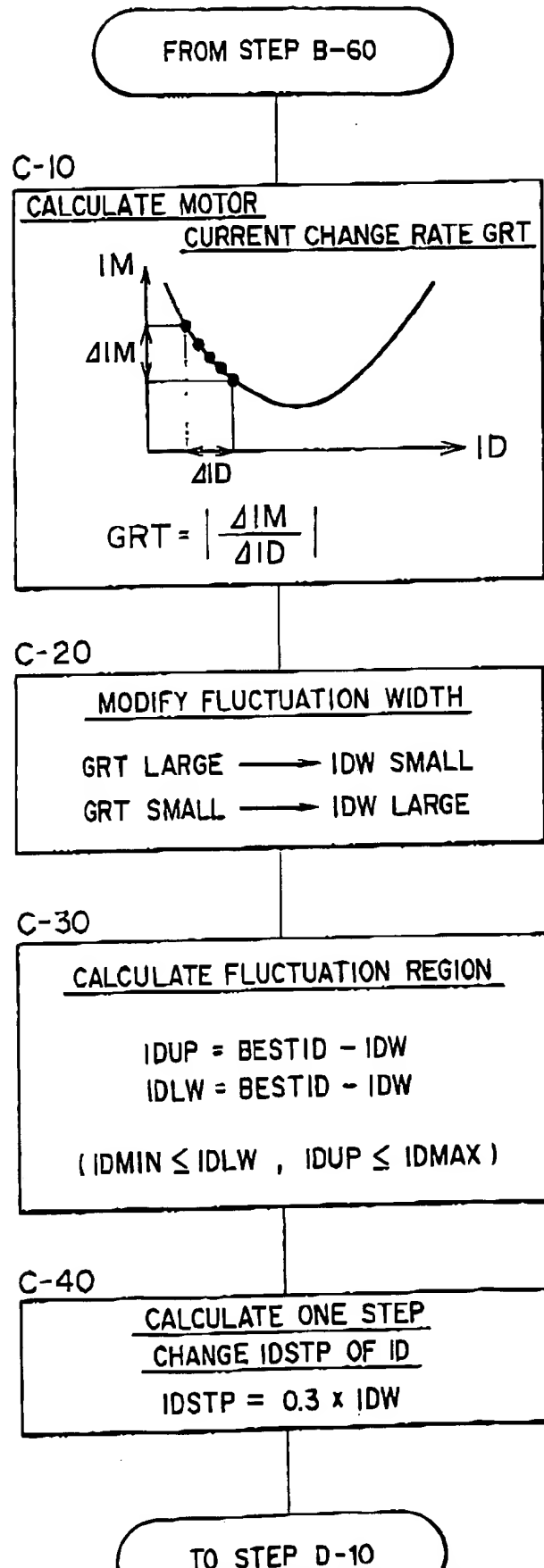
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FIG. 14



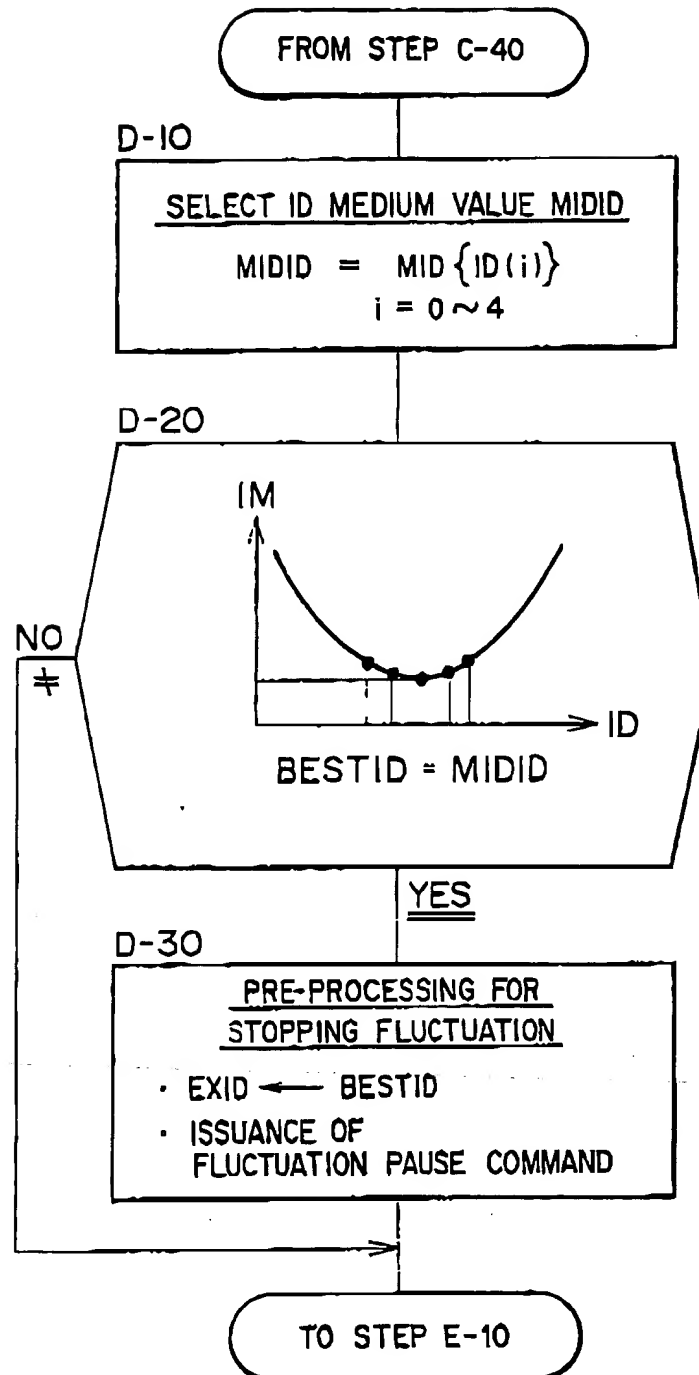
13/24

FIG. 15



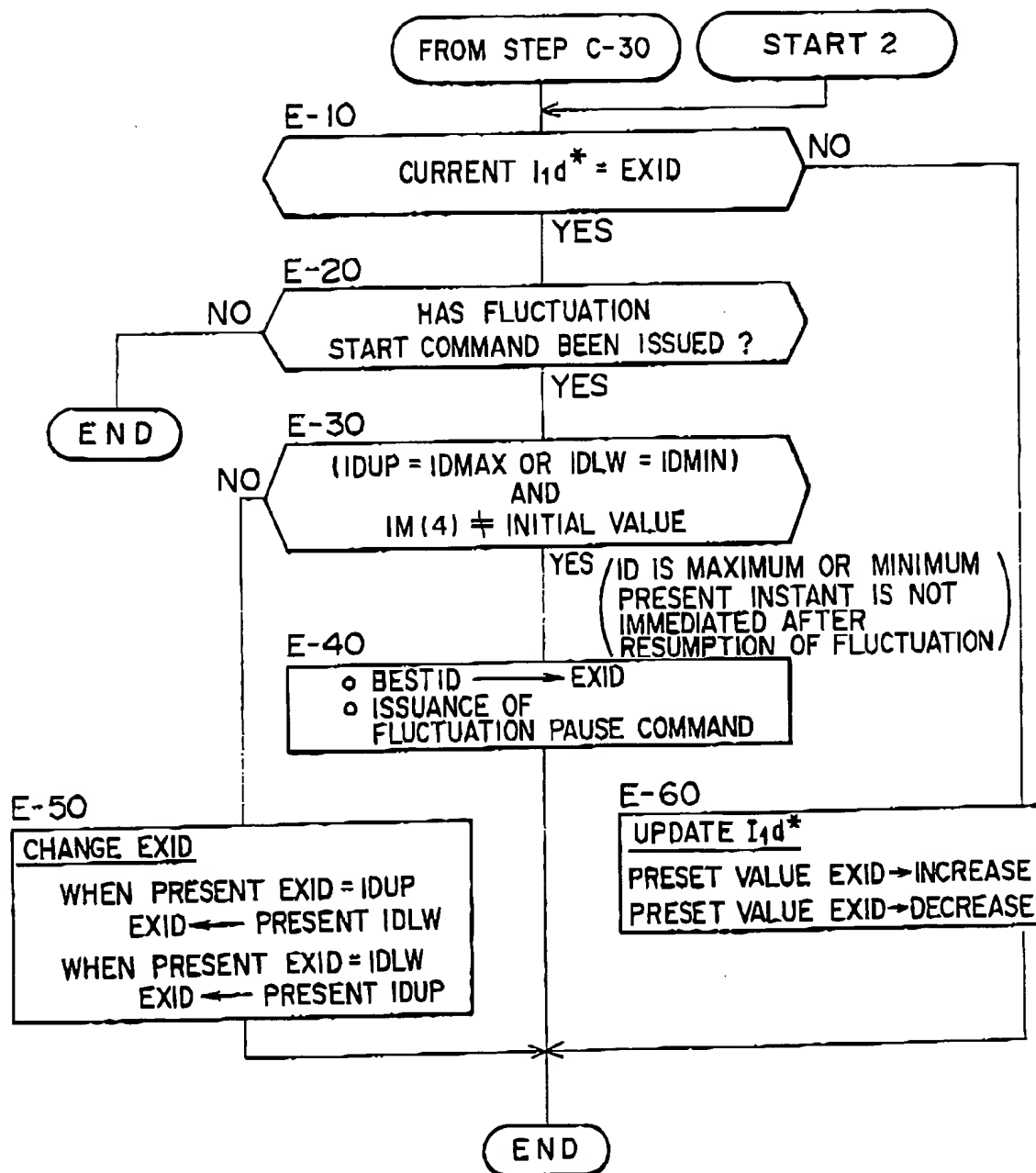
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FIG. 16



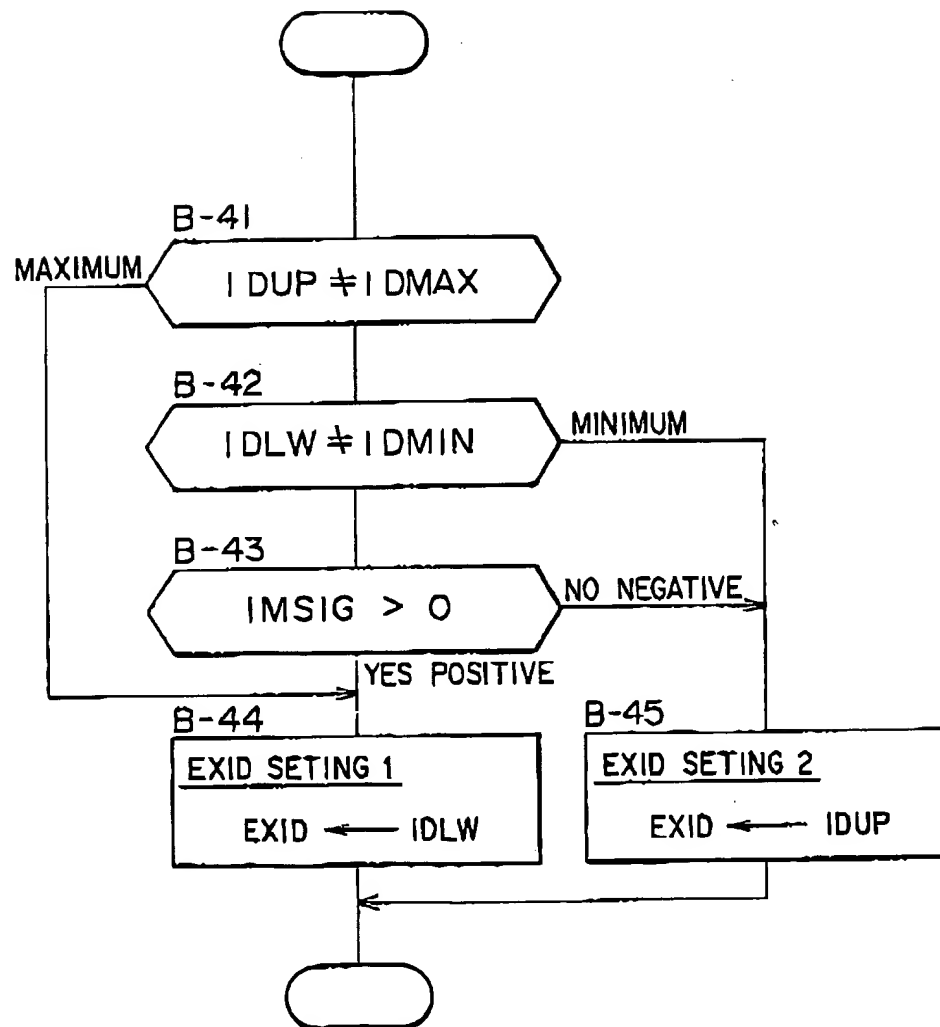
15/24

FIG. 17



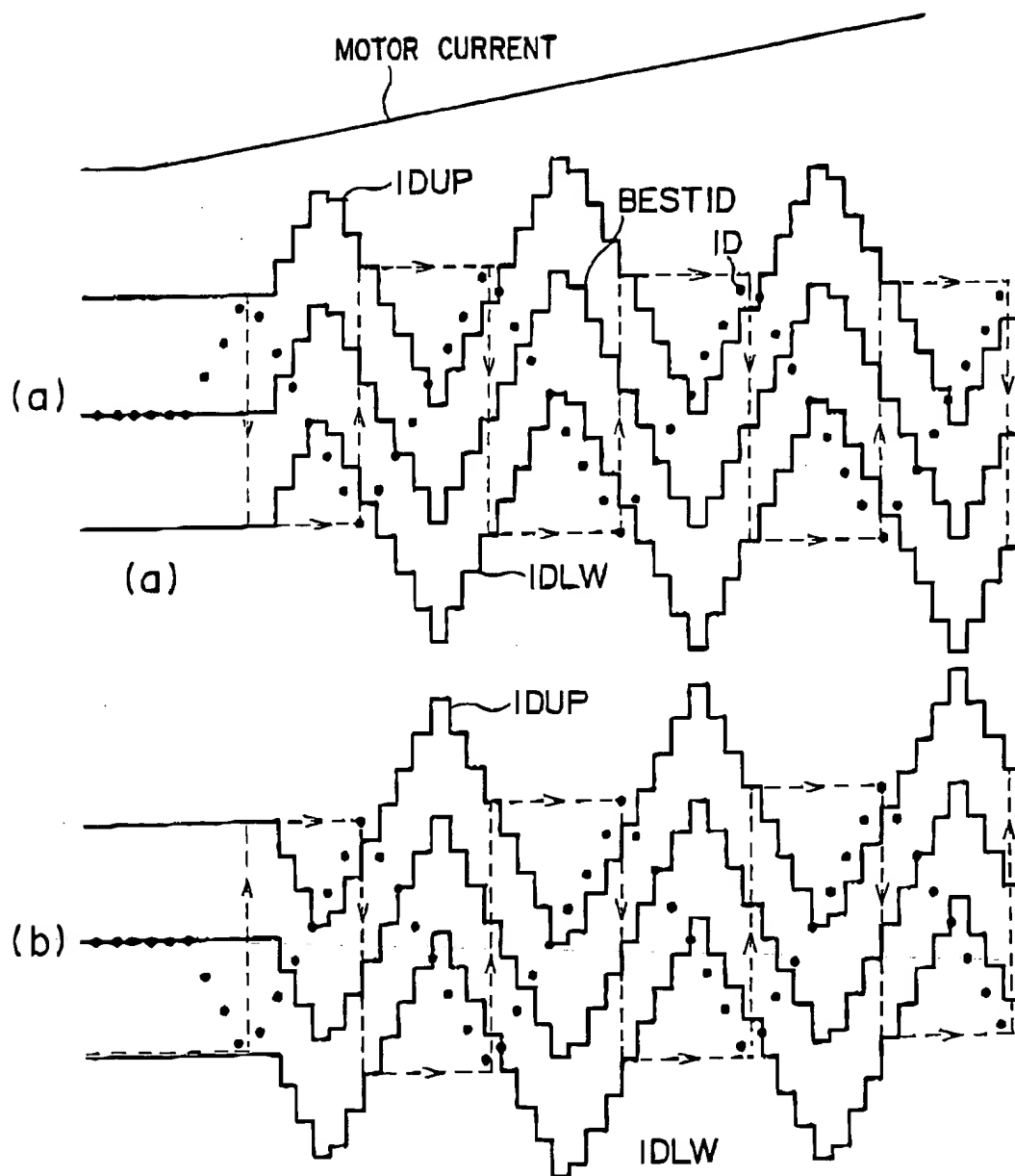
16/24

FIG. 18



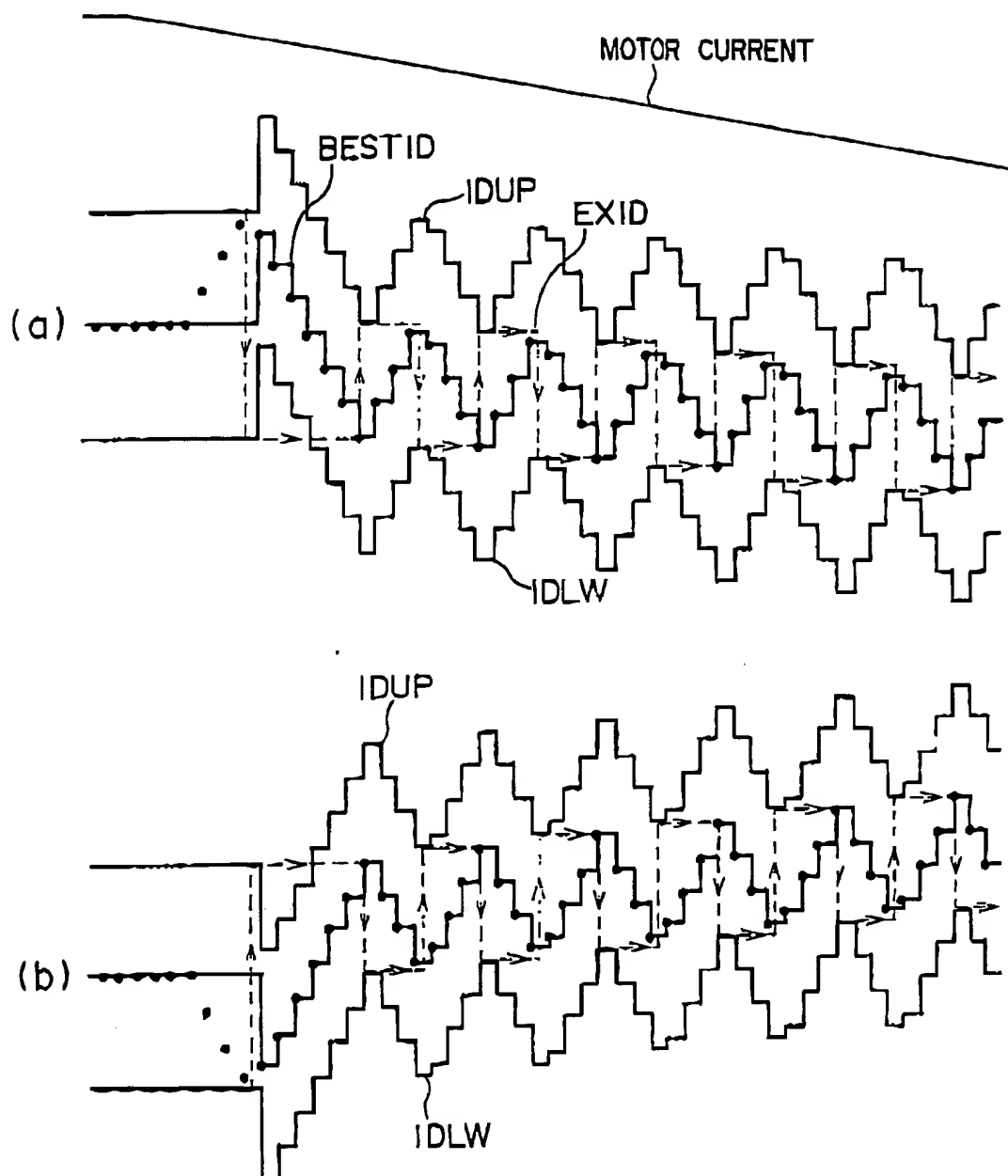
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FIG. 19



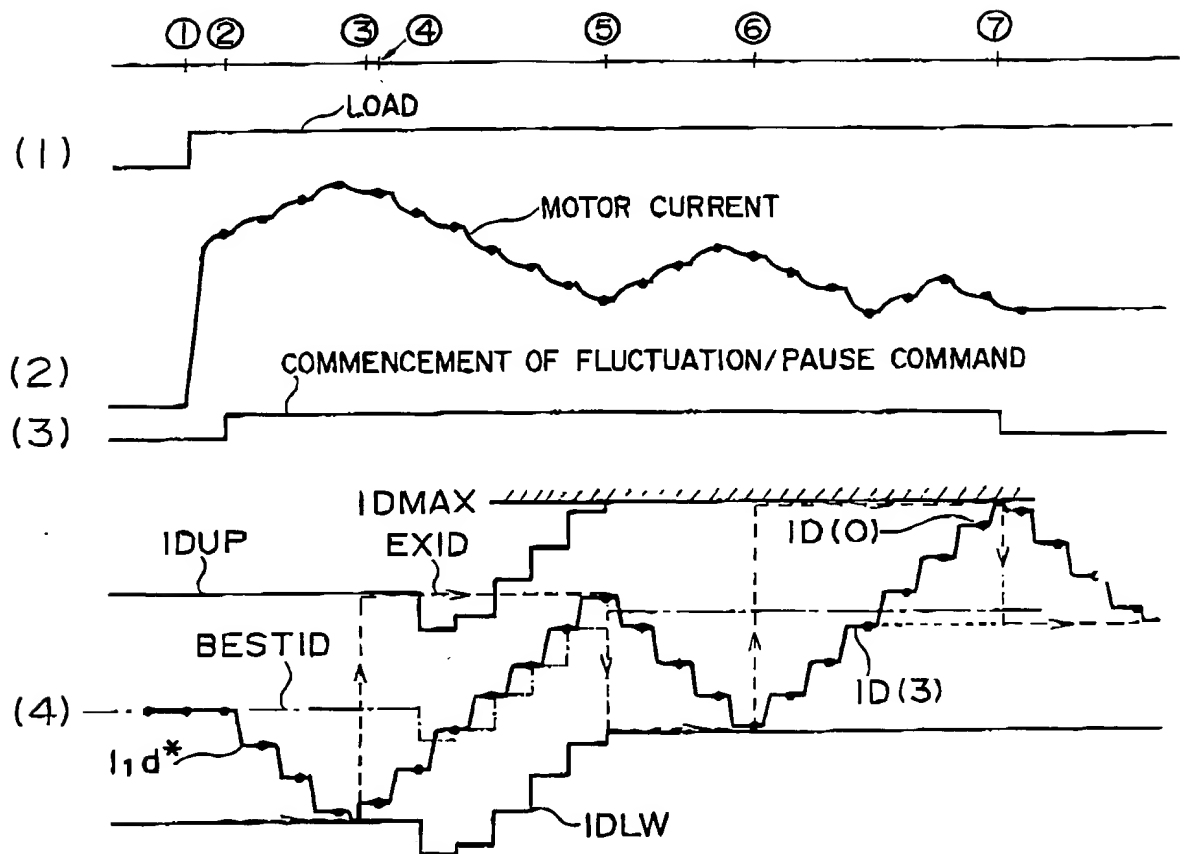
18/24

FIG. 20



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FIG. 21



20/24

FIG. 22

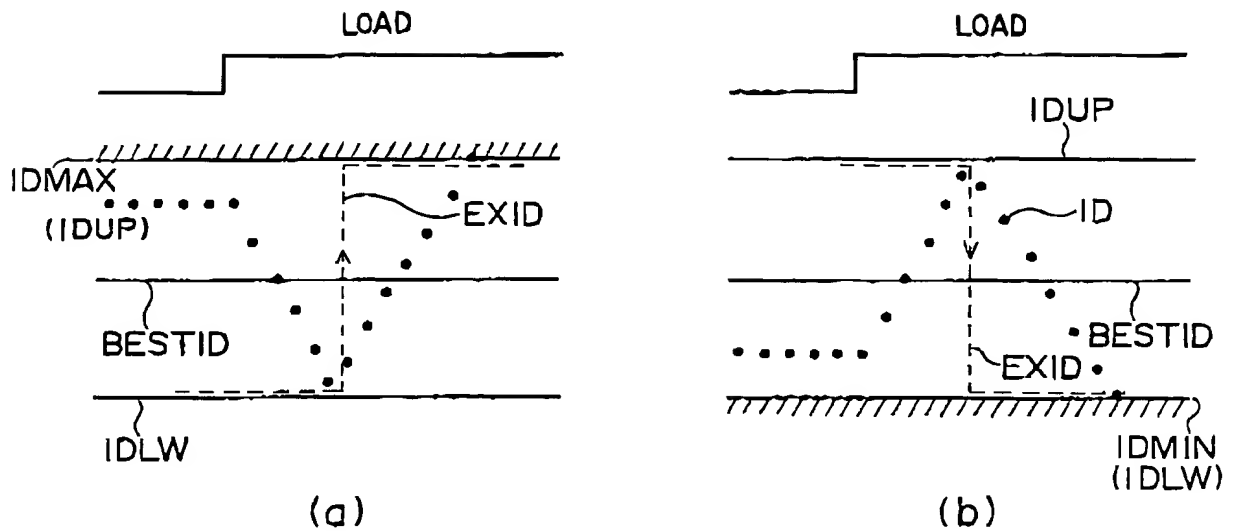
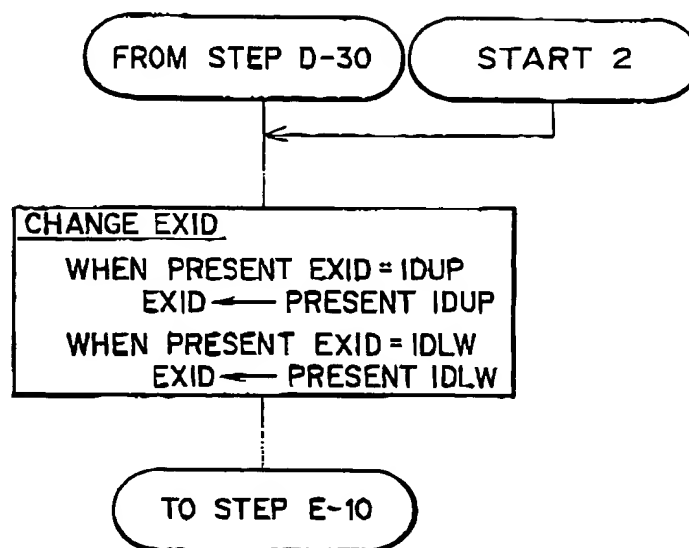
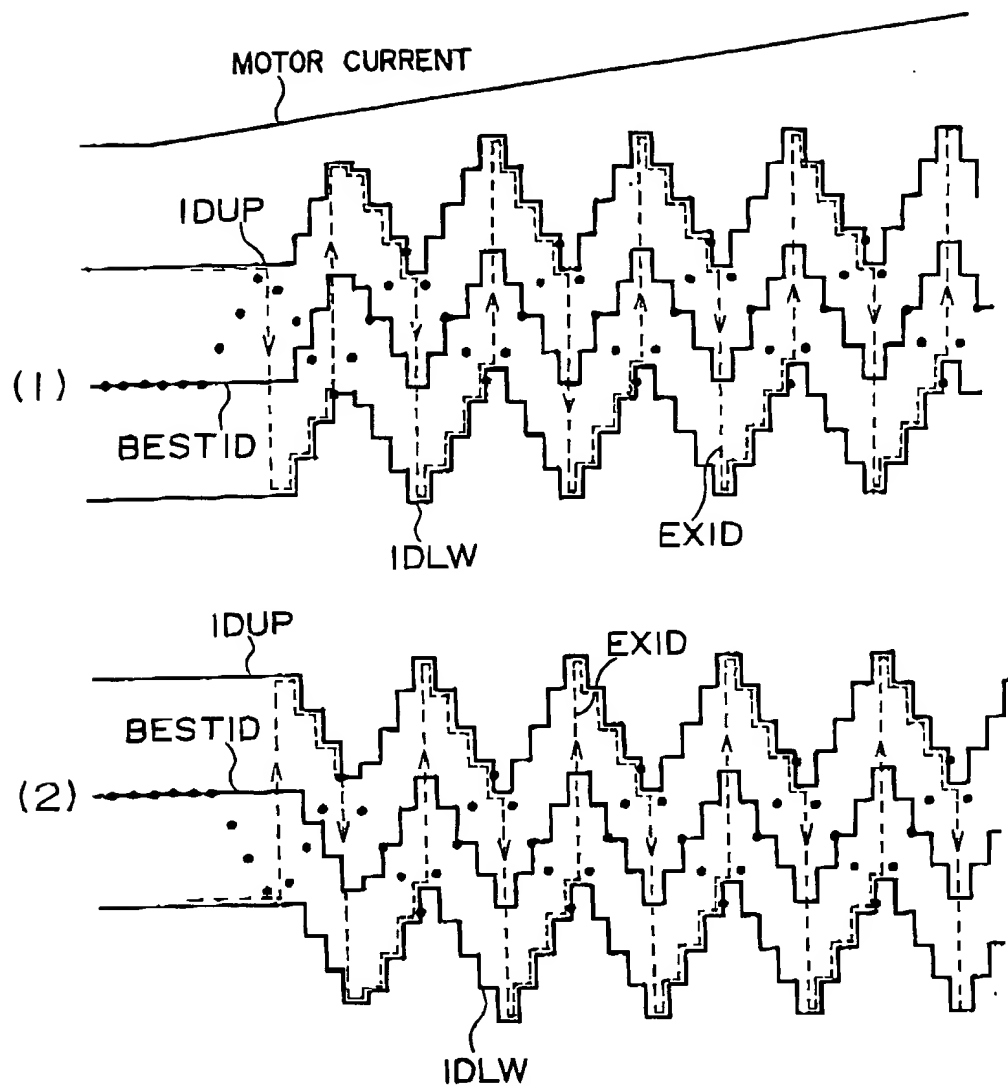


FIG. 23



21/24

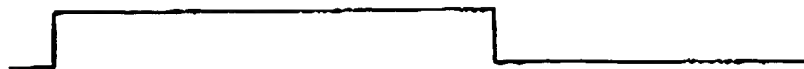
FIG. 24



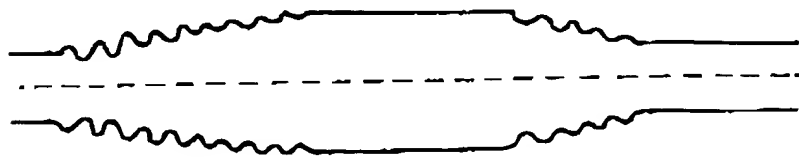
22/24

FIG. 25

(1) LOAD



(2) OUTPUT VOLTAGE



(3) WINDING CURRENT

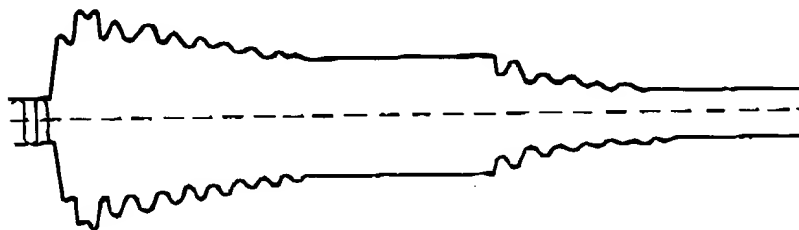
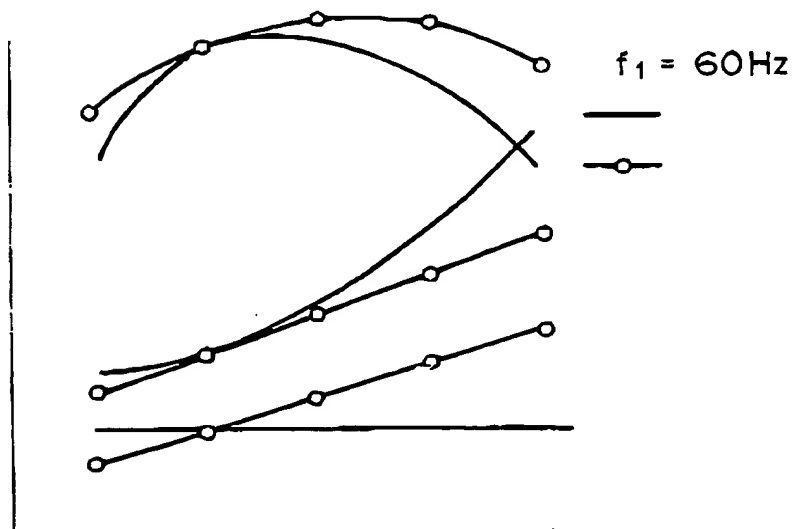
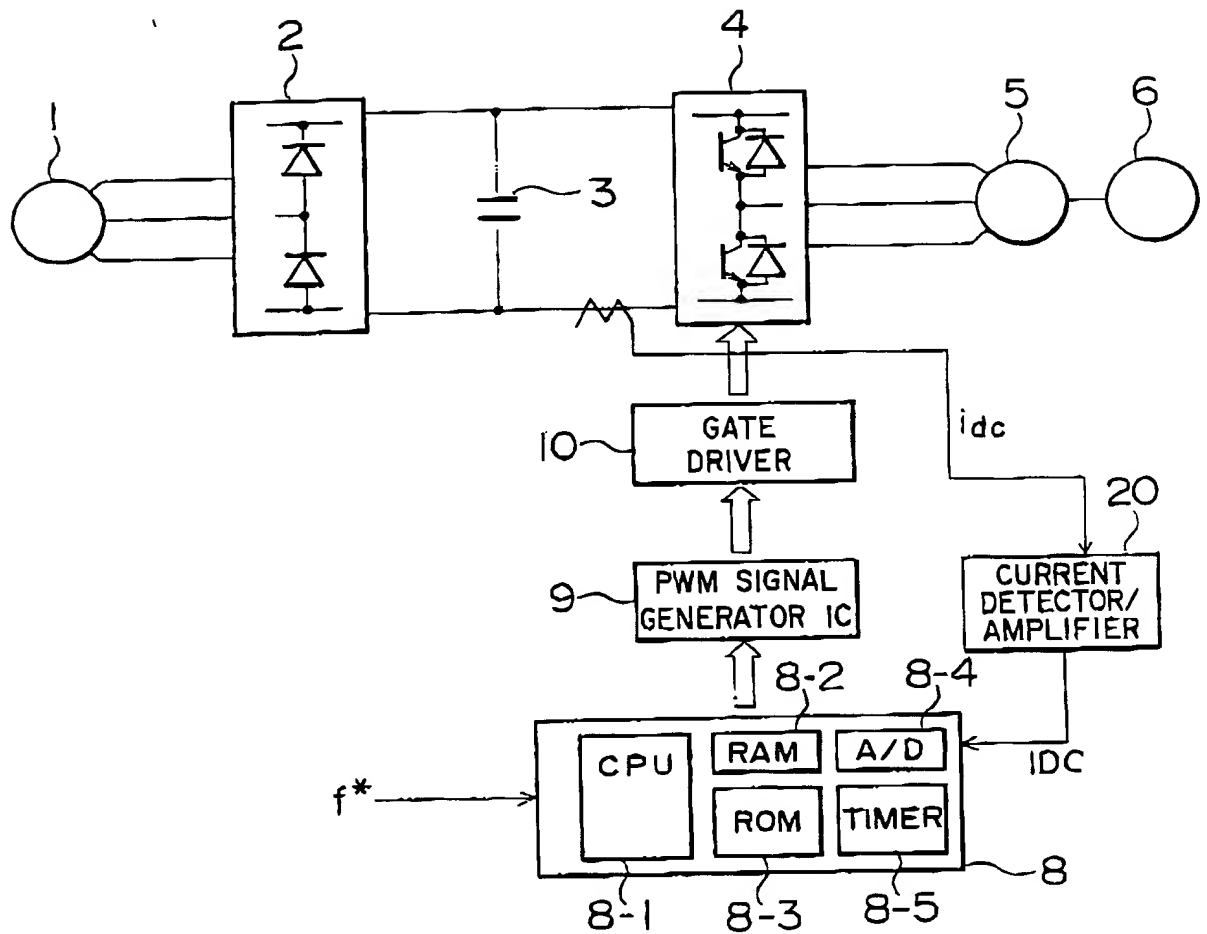


FIG. 26



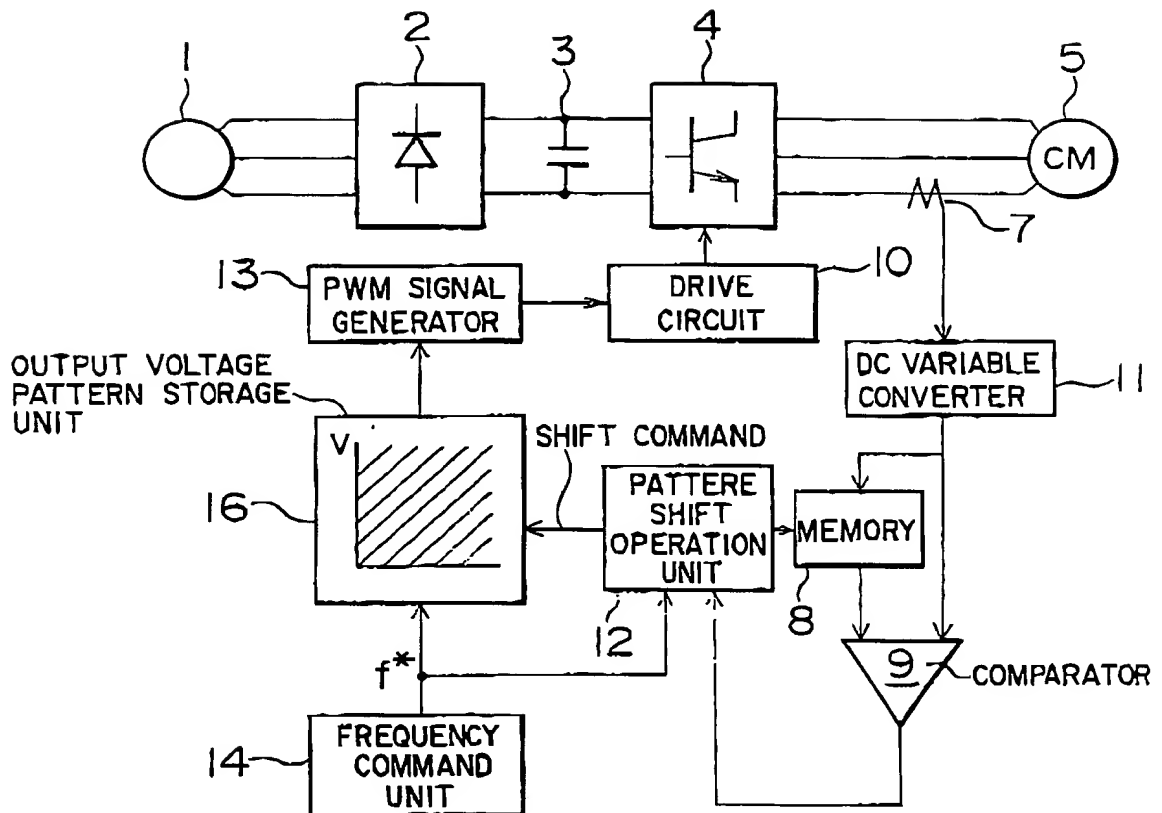
23/24

FIG. 27



$$24 \mid 24$$

FIG. 28



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- 1 -

METHOD AND APPARATUS FOR CONTROL OF INVERTER

1

The present invention relates to an inverter adapted to controllably drive an AC motor and more particularly to method and apparatus for control of the inverter which are directed to minimization control of motor current.

As an extremum search circuit used for a process control system and the like, one shown in JP-A-58-191004 is available. The disclosed circuit searches an extremum of a controlled variable in a control system in which the extremum of the controlled variable varying with a manipulated variable changes in accordance with a disturbance, and it is based on such a principle that a difference between a current controlled variable (value) and a preceding controlled variable (value) is determined every cycle at a predetermined period, the manipulated variable is further changed in the same direction as that in the preceding cycle if the difference value, i.e., the change occurs in a direction for approach to an extremum but the manipulated variable is changed in a direction opposite to that in the preceding cycle if the change occurs in a direction for departure from the extremum, and the above sequential operation is repeated to cause the controlled variable to be so controlled as to approach the extremum.

- 2 -

1 On the other hand, a method for minimization
control of motor current is known which is based on a
similar principle to the above, whereby output voltage
of an inverter is changed at a sampling time point,
5 motor current is detected when it subsequently becomes
stable, a difference between a detected value at a
preceding sampling time point and a current detected
value is determined, and the output voltage of the
inverter is changed in the same direction as that in the
10 preceding cycle if the motor current changes in its
decreasing direction but the output voltage of the
inverter is changed in a direction opposite to that in
the preceding cycle if the motor current changes in its
increasing direction, thus causing the motor current to
15 be so controlled as to approach a minimum value. As an
example of the method for minimization control of motor
current, a prior art method as shown in JP-A-62-51781
will now be described.

Fig. 28 shows a block diagram of the prior art
20 inverter apparatus. In the figure, reference numeral 1
designates a commercial AC power source, 2 a converter
for converting the output of the AC power source 1 into
direct current, 3 a DC smoothing circuit for smoothing
the DC output of the converter 2, 4 an inverter for
25 converting direct current from the DC smoothing circuit
3 into alternating current, 5 an AC motor driven by the
inverter 4, 7 a winding current detector/amplifier for
detecting and amplifying input current to the winding of

- 3 -

1 the AC motor 5, 11 a DC variable converter for convert-
ing a detected motor current value into a DC variable to
detect an average value of the motor current, 8 a memory
for storing the DC variable from the DC variable
5 converter, 9 a comparator for comparing data representa-
tive of the DC variable from the DC variable converter
11 with stored current value data, 12 a pattern shift
operation unit adapted to deliver an instruction for
shifting an output voltage pattern on the basis of
10 output data from the comparator 9 and a frequency
command f^* from a frequency command unit 14, and 16 an
output voltage pattern storage unit in which a number of
output voltage patterns of different output voltages V
having a constant ratio between their magnitudes and
15 frequencies F are stored and which responds to the
signal of frequency command f^* and the shift instruction
to deliver an output voltage command. Denoted by 13 is
a PWM signal generator for generating a pulse width
modulated signal (PWM signal) on the basis of the output
20 voltage command, and by 10 is a drive circuit for
driving switching elements of the inverter 4 on the
basis of the PWM signal.

In the conventional current minimization
control, running proceeds under a given output voltage
25 pattern A and a motor current value at that time is
detected and stored. Subsequently, running proceeds
under an output pattern (A+1) and after a predetermined
time delay, a motor current value at that time is

- 4 -

1 compared with the previously stored motor current value.
If a decrease in the current is determined, the output
voltage pattern is shifted to (A+2) of increased
voltage. Conversely, if an increase in the current
5 value is determined when the output voltage pattern is
shifted from A to (A+1), the output voltage pattern is
shifted to (A-1) of decreased voltage. In this manner,
the output voltage pattern is shifted in a direction for
decreasing the current value and when the current value
10 increases from the preceding current value, the preceding
output voltage pattern is decided to be optimum and
is then fixed. This value is kept until the output
frequency changes.

The conventional extremum search method and
15 inverter control apparatus for minimization of motor
current have constructions described as above and
therefore they face a problem that when the disturbance
or motor load changes or when the motor runs with its
speed increased or decreased, an optimum manipulated
20 variable (value) at which an extremum of the controlled
variable is given or an optimum output voltage at which
the motor current is minimized cannot be searched out.
In the case of an inverter apparatus for minimization
of, for example, motor current, as the load decreases
25 continuously and the motor current value decreases
sympathetically, the motor current decreases regardless
of the direction in which the output voltage of the
inverter changes. Since in this case it is impossible

- 5 -

1 to decide whether the motor current decreases on account
of a decrease in load or on account of a change in
output voltage, there sometimes occurs an inconvenience
that the output voltage is fixed to a value indicative
5 of not-optimum voltage or a divergent phenomenon that
the output voltage is caused to continue increasing or
decreasing. Similar problems also take place when the
motor current value is erroneously detected owing to
noise and the like.

10

The present invention intends to solve the
above problems and its object is to provide inverter
control method and apparatus which are immune to the
influence of load disturbance and detection noise to
15 permit stable minimization control of motor current in
order to attain high efficiency of an AC motor and an
inverter adapted to drive the motor.

According to the invention, in a method of
controlling an inverter in which the inverter receiving
20 direct current and delivering alternating current con-
trollably drives an AC motor by using its AC output
voltage as a manipulated variable, when motor current
increases or decreases starting from a running state at
which input current to the motor is constant, the mani-
25 pulated variable is changed at a running state subject
to an increased or decreased motor current to pulsate
the motor current and is sequentially determined in a

- 6 -

1 direction in which an average value of the pulsating
motor current decreases gradually.

In a specific method for this purpose, a fluctuation region is set up to permit the manipulated variable to fluctuate within a range defined by predetermined upper and lower limit values, and the fluctuation region is moved as the time elapses in a direction in which at least one of a change width and a change rate of the input current or output current of the inverter
10 standing for a controlled variable is decreased.

For the fluctuation region, a first target value and a second target value are set which are defined by the upper and lower limit values, respectively, the manipulated variable is changed to approach one
15 of the target values and when the manipulated variable tends to exceed the one target value, the other target value is set to an upper limit value or a lower limit value at that time, the manipulated variable is changed to approach the thus set target value and the two target
20 values are moved as the time elapses in a direction in which at least one of a change width and a change rate of the controlled variable decreases gradually.

For movement of the fluctuation region, there are provided a plurality of sets of paired data pieces
25 of manipulated variables and corresponding controlled variables which are obtained before movement, a manipulated variable of a set having a corresponding controlled variable which is an extremum is selected

- 7 -

1 from the plurality of sets, and the fluctuation region
of manipulated variable is decided sequentially such
that the selected manipulated variable falls within the
fluctuation region.

5 The fluctuation width of the fluctuation
region is so selected as to be small when the absolute
value of a rate of change of the controlled variable
relative to the manipulated variable is large but to be
large when the absolute value of the change rate is
10 small.

 The manipulated variable and the corresponding
controlled variable are put together to set up a set, at
least three are stored in a memory group, a memory of
one set of the manipulated variable and controlled
15 variable is updated every predetermined period in the
memory group, a manipulated variable of a set having a
corresponding controlled variable which is an extremum
is selected from the memory group, the fluctuation
region is so reset that the selected manipulated
20 variable may fall within the fluctuation region, and a
next value of the manipulated variable is set in a
direction in which the selected manipulated variable
approaches an upper limit value or a lower limit value
of the fluctuation region.

25 In the inverter control of the present inven-
tion, the output voltage standing for the manipulated
variable is determined in the manner described as above
and therefore when an increase or a decrease in load,

- 8 -

1 for example, causes the motor current to increase or
decrease irrespective of the magnitude of the output
voltage or when the motor current is detected erroneously
on account of noise or the like, the output voltage
5 can be controlled so as to minimize the motor current.

More particularly, the concept of a fluctuation region is newly introduced into the output voltage standing for the manipulated variable, so that the existence of the upper and lower limit values in the fluctuation region can prevent the output voltage from keeping
10 increasing or decreasing excessively in a wrong direction. In addition, by moving the fluctuation region of output voltage defined by the upper and lower limit values in a direction in which the motor current is made
15 to be smaller, the output voltage is caused to approach a value for minimization of the motor current while being pulsated. At that time, even in the presence of an erroneous detection of load change or motor current, the output voltage per se is still permitted to
20 fluctuate only between the upper and lower limit values defining the fluctuation region. The direction of movement of the fluctuation region will be explained.

Firstly, in the case of erroneous detection of motor current due to noise and the like, the fluctuation
25 region is once modified in a wrong direction but the motor current is constantly determined in its decreasing direction and so the wrong modification can be corrected. Then, in case where as the load increases

- 9 -

1 gradually, current increases gradually regardless of the
output voltage being fluctuated, the current increases
incessantly and so the direction in which the motor
current is made to be smaller cannot be found, with the
5 result that the fluctuation region is prevented from
continuing moving and brought into a hold state.
Further, in case where as the load decreases gradually,
current decreases gradually regardless of the output
voltage being fluctuated, the current decreases
10 incessantly and so the fluctuation region per se also
moves up and down in accordance with fluctuation of the
output voltage, with the result that the fluctuation
region does not move in the same direction, either.

Also, in accordance with the present
15 invention, it is not until the motor current changes
from a running state of constant motor current owing to,
for example, a change in load that the output voltage is
so determined while the motor current being fluctuated
up and down that the average of the fluctuation is made
20 to be smaller, whereby erroneous detection of the motor
current and an excessive increase or decrease in current
due to the load change can be prevented.

Further, according to the invention, three or
more sets of paired data pieces of motor current and
25 output voltage are provided and an output voltage of a
paired data piece having a minimum motor current can be
used as a reference for determination of the direction
of a new output voltage, thereby ensuring that immunity

- 10 -

1 to detection noise can be improved as compared to the
conventional method in which the next output voltage is
determined in accordance with a gradient between two
points representative of different sets of motor current
5 and output voltage.

In the drawings:

Fig. 1 is a diagram for explaining an embodi-
ment of dynamic characteristics of the invention
obtained when the load changes stepwise;

10 Fig. 2 is a diagram showing the construction
of a control system to which the invention is applied
and characteristics of the control system;

Fig. 3 shows graphically characteristics of an
embodiment of a control system according to the
15 invention;

Fig. 4 is a graph useful to explain the main
point of an embodiment of the invention;

Fig. 5 is a block diagram showing an overall
construction of an embodiment of an inverter apparatus
20 according to the invention;

Fig. 6 is a block diagram showing a construc-
tion of the essential part of the embodied inverter
apparatus;

Fig. 7 is a diagram useful to explain the
25 operation of the essential part in a current detection
method applied to the embodied inverter apparatus;

Fig. 8 is a diagram showing a structure of a

- 11 -

1 main memory of the embodied inverter apparatus;

Fig. 9 is a diagram useful to explain an exciting current command fluctuation method applied to the embodied inverter apparatus;

5 Fig. 10 is a diagram useful to explain another exciting current command fluctuation method applied to the embodied inverter apparatus;

Fig. 11 is a flow chart showing a construction of a main control processing in the embodied inverter
10 apparatus;

Fig. 12 is a timing chart for explaining the timing for execution of the main control processing in the embodied inverter apparatus;

Fig. 13 is a flow chart showing a detailed
15 construction of a first step of the main control processing in the embodied inverter apparatus;

Fig. 14 is a flow chart showing a detailed construction of a second step of the main control processing in the embodied inverter apparatus;

20 Fig. 15 is a flow chart showing a detailed construction of a third step of the main control processing in the embodied inverter apparatus;

Fig. 16 is a flow chart showing a detailed construction of a fourth step of the main control
25 processing in the embodied inverter apparatus;

Fig. 17 is a flow chart showing a detailed construction of a fifth step of the main control processing in the embodied inverter apparatus;

- 12 -

1 Fig. 18 is a flow chart showing a detailed construction of a sixth step of the main control processing in the embodied inverter apparatus;

 Fig. 19 is a diagram for explaining an example
5 of operation of the embodied inverter apparatus;

 Fig. 20 is a diagram for explaining another example of operation of the embodied inverter apparatus;

 Fig. 21 is a diagram for explaining still another example of operation of the embodied inverter
10 apparatus;

 Fig. 22 is a diagram for explaining still another example of operation of the embodied inverter apparatus;

 Fig. 23 is a flow chart for explaining a
15 construction of a modification of the invention in which the essential part of the embodied converter apparatus is modified;

 Fig. 24 is a diagram for explaining the operation of the modified inverter apparatus;

20 Fig. 25 is a diagram for explaining how to change output voltage and winding current in the embodied inverter apparatus;

 Fig. 26 is a graph useful in explaining effects of the embodied inverter apparatus;

25 Fig. 27 is a block diagram showing an overall construction of another embodiment of an inverter apparatus according to the invention; and

- 13 -

1 Fig. 28 is a block diagram for explaining a
prior art example of control.

5 The present invention will now be described by
way of example with reference to the accompanying
drawings.

Referring to Figs. 2 to 4, the basic concept
of embodiment of the invention will first be described.

10 Shown in Fig. 2 are a diagram illustrating a
general construction of the invention and a graph
depicting characteristics of a control system to which
the invention is applicable. As shown at section (a) in
Fig. 2, an extremum search circuit 100 receives a
controlled variable z and delivers a manipulated
15 variable m . The manipulated variable m is amplified
with an amplifier 200 and then inputted to a process
300. The process is applied with a disturbance d and it
delivers outputs of which one serves as the controlled
variable z . The manipulated variable is related to the
20 controlled variable as graphically shown at (b) in Fig.
2. Namely, for a constant disturbance, there is a
manipulated variable (value) at which the controlled
variable assumes an extremum (a minimum in Fig. 2). The
aforementioned extremum search circuit searches extrema
25 to determine the manipulated variable at which the
extremum is provided.

- 14 -

1 When specifying the general construction
diagram shown at (a) in Fig. 2 by regarding the process
as an induction motor, the amplifier as an inverter for
driving the induction motor, the controlled variable as
5 winding current flowing in the induction motor and the
disturbance as load torque of the induction motor and/or
output frequency of of the inverter, the manipulated
variable corresponds to output voltage of the inverter.
Examples of graphical representations of characteristics
10 corresponding to those at (b) in Fig. 2 are shown at (a)
to (c) in Fig. 3. More particularly, as known in the
art, winding current flowing in the induction motor has
the magnitude which changes with the magnitude of
voltage (output voltage of the inverter) applied to its
15 winding and an output voltage exists at which a minimum
value of the winding current is provided.

When searching extrema, the winding current
standing for the controlled variable is detected but
disadvantageously, because of pulsating components and
20 noises contained in a detected value, the output voltage
is related to the detected value through local extrema
occurring as shown by dotted curve at (b) in Fig. 3.
On the other hand, when the load torque and the
frequency change, many extrema take place as shown at
25 (c) in Fig. 3.

To prevent an erroneous decision of mistaking
the local extrema occurring during the extremum search
and temporary extrema occurring upon the change of

- 15 -

1 disturbance for true extrema, an extremum search circuit
of the invention may first provide output voltage stand-
ing for the manipulated variable with either a fluctua-
tion region or two target values of change of the output
5 voltage so that the fluctuation region or the two target
values may be moved towards a direction in which an
extremum exists.

An embodiment of the invention will now be
described specifically.

10 <Overall Construction>

Fig. 5 is a block diagram showing a schematic
construction of an inverter apparatus according to the
invention. Exemplarily, in the embodiment to be
described here, an induction motor for drive of a
15 compressor constituting an air conditioner or a refrig-
erator is operated at varying speeds by means of the
inverter apparatus. In Fig. 5, components designated by
reference numerals 1 to 5 are the same as those of Fig.
28 and will not be described herein. Reference numeral
20 6 designates a compressor loaded on the induction motor,
7 a winding current detector/amplifier adapted to detect
and amplify winding currents i_u and i_v flowing in the
winding of the induction motor 5, and 8 a control/operation
unit inputted with an output frequency command f^*
25 for the inverter and current signals I_U and I_V from the
winding current detector/amplifier to deliver time data.
The control/operation unit includes a microcomputer of

- 16 -

1 CPU 8-1, a memory of RAM 8-2 and ROM 8-3, an A/D
converter 8-4 and a timer 8-5. Denoted by 9 is a PWM
signal generator IC for generating a PWM signal in
accordance with the time data from the control/operation
5 unit 8 and by 10 is a gate driver responsive to the PWM
signal to generate drive signals for driving the gates
of a plurality of switching elements.

In the control/operation unit 8, a control
operation corresponding to the operation of the extremum
10 search circuit shown in Fig. 2 is executed. Fig. 6
shows a control/operation block corresponding to the
extremum search circuit. In Fig. 6, reference numeral
11 designates a DC variable converter responsive to the
winding current detected values IU and IV produced from
15 the winding current detector/amplifier 7 to generate a
motor current I1 in the form of a DC variable, 12 a
memory group for storing a plurality of sets of motor
current I1 and exciting current command Ild* to be
described later which stands for the manipulated
20 variable, 13 a comparator for comparison of magnitudes
of the plurality of motor currents or magnitudes of the
plurality of exciting current commands mainly stored in
the memory group 12, 14 a fluctuation region operation
unit for determining, on the basis of a comparison
25 result produced from the comparator 13, a region in
which the exciting current command Ild* is fluctuated,
15 an exciting current command operation unit for
determining a value by which the exciting current

- 17 -

1 command I_{ld}^* is to be changed actually in accordance
with a result produced from the fluctuation region
operation unit 14, 16 a voltage operation unit respon-
sive to the inverter output frequency command f^* and
5 exciting current command I_{ld}^* to calculate an output
voltage command V^* of the inverter, and 17 a PWM signal
time data generator responsive to the output frequency
command f^* and output voltage command V^* of the inverter
to determine time data for output voltage of the
10 inverter.

Since in this embodiment the output voltage
command V^* of the inverter is given pursuant to expres-
sion 1 to control the output voltage by selecting the
exciting current command I_{ld}^* as a parameter for chang-
15 ing the output voltage of the inverter, the exciting
current command serves as the manipulated variable in
the present embodiment. It is to be noted that the
output voltage command V^* is proportional to the
exciting current command I_{ld}^* as will be seen from
20 expression 1 and therefore, obviously, the output
voltage command may alternatively be used as the
manipulated variable.

[Expression 1]

$$V^* = I_{ld}^* \cdot I_m \cdot 2 \cdot \pi \cdot f^*$$

where V^* : output voltage command
25 I_{ld}^* : exciting current command

- 18 -

- 1 l_m : exciting inductance
 f^* : output frequency command.

The major part of the extremum search shown in Fig. 6 will now be described in greater detail.

5 <Motor Current Detection>

Fig. 7 is a diagram illustrative of the contents of processing in the DC variable converter 11. This processing is executed every short sampling period T_s and consists of five kinds of contents.

- 10 (1) The winding current detected values I_U and I_V delivered out of the winding current detector/amplifier 7 are converted by the A/D converter 8-4 into digital variables which in turn fetched into the control operation unit 8.
- 15 (2) The remaining winding current I_W is determined pursuant to expression 2.
 [Expression 2]

$$I_W = - I_U - I_V.$$

- (3) Full-wave rectified values $|I_U|$, $|I_V|$ and $|I_W|$ of three-phase winding currents are determined.
- 20 (4) A maximum value is determined every short sampling period by comparing the full-wave rectified values of respective phases.
- (5) The aforementioned maximum value is subjected to filtering process to provide the motor current I_1 .

- 19 -

1 As described above, in the present embodiment,
the motor current I_l determined with the DC variable
converter 11 is treated as a detected variable of the
winding current standing for the controlled variable and
5 an exciting current command is searched which minimizes
the motor current I_l .

<Structure of Memory and Storage of Data>

The RAM 8-2 shown in Fig. 5 has a major RAM
related to the invention for which the memory group 12
10 shown in Fig. 6 is used having such a structure as will
be described with reference to Fig. 8. As shown in Fig.
8, five pieces of motor current data $IM(0)$ to $IM(4)$ and
five pieces of exciting current command data $ID(0)$ to
 $ID(4)$ are stored in the memory group 12. Data of motor
15 current I_l and exciting current command I_{ld}^* is obtained
every long sampling period T_l to be described later and
a set of $IM(0)$ and $ID(0)$ represents new data obtained
currently during the period T_l . Motor current and
exciting current command preserved at a sampling cycle
20 preceding by i are represented by $IM(i)$ and $ID(i)$.

<Rule for Fluctuation of Exciting Current Command>

A basic rule in a method of fluctuating
exciting current command will now be described with
reference to Figs. 9 and 10. A first point of the rule
25 is as follows.

- 20 -

1 In order to give a fluctuation region to an
exciting current command to be fluctuated, an upper
limit value IDUP and a lower limit value IDLW are set
and when the exciting current command has already been
5 inside the fluctuation region, exciting current is
changed toward a target value of either the upper limit
value or the lower limit value as shown at (a) in Fig.
9. Conversely, when the exciting current command is
outside the fluctuation region as shown at (b) in Fig.
10 9, exciting current is so changed as to lie inside the
fluctuation region. In the figure, the aforementioned
target value EXID is indicated by dotted line and a
medium value between the upper and lower limit values is
defined as a reference exciting current command BESTID.
15 A black dot mark in the figure denotes a timing for
storing the motor current data IM(0) and exciting
current command data ID(0) in the memory group 12.

A second point of the rule is such that within
the fluctuation region, two modes are set up of which
20 one is for making the exciting current constant and the
other is for changing the exciting current stepwise.
The magnitude of the exciting current to be made to be
constant is so selected that a few levels can be set up
within the width of the fluctuation region. In the
25 present embodiment, a step width IDSTP representative of
a difference between a certain constant exciting current
level and a level next to it is so selected as to be 30%
of half the width of the fluctuation region. It is

- 21 -

1 noted that the half of the fluctuation region width is simply referred to as a fluctuation width IDW in the present embodiment.

It is also noted that, in the present embodiment, as the exciting current command on an excursion of the change mode reaches a target value, the direction of change is switched to a new target value which is the upper limit value or lower limit value as viewed from the presently reached target value.

10 A third point of the rule is such that a maximum value IDMAX and a minimum value IDMIN are provided for the exciting current command per se and fluctuation regions of exciting current are determined within a range defined by the maximum and minimum values as shown in Fig. 10. More specifically, the relation
15 pursuant to expression 3 is always satisfied.

[Expression 3]

$$IDUP \leq IDMAX$$

$$IDLW \geq IDMIN.$$

<<Specific Control Method>>

<Processing Construction and Execution Timing>

20 A specific control processing method for extremum search grounded on the previously-described motor current detection method, data storage method and rule for fluctuation of exciting current command will be described with reference to Figs. 11 to 22.

- 22 -

1 Fig. 11 is a flow chart showing the construc-
tion of processing. The whole control processing is
mainly divided into five kinds of contents including
processing blocks A to E to be described below.

5 In processing block A which is a BESTID
selection processing, movement of data in the memory
group 12 is carried out, minimum motor current data is
selected from the five pieces of motor current data
IM(0) to IM(4), and exciting current command data
10 corresponding to the selected minimum motor current data
is found out to provide a BESTID. In processing block B
which is an ID fluctuation start processing, while a
change amount of motor current being prepared, the
exciting current command is decided as to whether to be
15 fluctuated depending on whether the change amount
exceeds a predetermined magnitude and when the condition
is satisfied, preparation for fluctuation is carried
out. In processing block C, a fluctuation region of
exciting current command defined by upper limit value
20 IDUP and lower limit value IDLW is determined in
accordance with the BESTID selected in block A. In
processing block D, the aforementioned BESTID is checked
for its being an optimum exciting current command which
minimizes the motor current and if so, preparation for
25 stopping fluctuation of exciting current is carried out.
In the final ID fluctuation processing, the exciting
current command is changed in accordance with the rul
for changing the exciting current described previously.

- 23 -

1 The processing blocks A to D are executed
every long sampling period T_l and the processing block E
is executed repetitively every short sampling period T_s
by cycles to be described later during the long sampling
5 period. The above will be detailed with reference to
Fig. 12. Shown at (1) in Fig. 12 is the movement of the
process managing timer, indicating that the long sampl-
ing period T_l equals one period. Shown at (2) in Fig.
12 is the change of the exciting current command,
10 indicating that time for one set of the constant mode
and change mode of exciting current command described
previously amounts to T_l . Shown at (3) in Fig. 12 is
the timing for execution of the current detection
processing to be executed in the DC variable converter
15 11 as described previously, indicating that the timing
occurs at the short sampling period and provides a time
base of the process managing timer. Then, as shown at
(4) in Fig. 12, the processing block E is executed
repetitively by cycles through which the exciting
20 current command reaches the next constant level, thus
completing the change mode of the exciting current
command. The other processing blocks are sequentially
executed at a timing shown at (5) in Fig. 12.

The contents of each control block will now be
25 described.

<BESTID Selection Processing>

Fig. 13 shows the contents of the BESTID

- 24 -

1 s lection processing. This processing is mainly divided
into three steps A-10 to A-30. In step A-10, movement
of data in the memory group 12 is carried out and in
step A-20, an exciting current command and a motor
5 current at that time are stored, as ID(0) and IM(0),
respectively, in the memory group 12. In step A-30,
minimum motor current data is selected from the motor
current data pieces IM(0) to IM(4) stored in the memory
group and an exciting current command corresponding to
10 the selected data is determined to be a BESTID.

<ID Fluctuation Start Processing>

The ID fluctuation start processing shown in
Fig. 14 has the contents including steps B-10, B-20, B-
30, B-40, B-50 and B-60. In step B-10, a difference
15 between the motor current data pieces IM(0) and IM(1)
stored in the memory group, i.e., a difference between
motor current data obtained at the present sampling time
and that obtained at the preceding sampling time is
added to a motor current change integrated value IMSIG
20 to update the same. Then, the magnitude of an absolute
value of a thus resulting IMSIG is decided as to whether
to exceed a fluctuation start allowable value IMLV (step
B-20).

With the absolute value of IMSIG exceeding
25 IMLV, it is decided whether the fluctuation of the
exciting current command is ceasing at that time (step
B-30), and if the fluctuation is ceasing, the procedure

- 25 -

1 proceeds to step B-40. In step B-40, preparation for
commencement of the fluctuation is carried out. More
specifically, a fluctuation start command is issued, a
fluctuation target value EXID is set and data pieces
5 IM(1) to IM(4) in the memory group are set to initial
values. The procedure then proceeds to the next step B-
50. Selected as the initial values are values which do
not exist as motor current values, for example, maximum
values of 7FFFH for 2-byte data. On the other hand,
10 when the fluctuation start condition is not satisfied in
step B-20, the procedure proceeds directly to step B-50.
If step B-30 indicates that the fluctuation has already
been in progress, the procedure proceeds to step B-60.
How to set a fluctuation target value will be described
15 later.

Then, if no fluctuation start command is
issued (step B-50) or fluctuation is even in progress
with the data IM(4) in the memory group set to the
initial value (step B-60), the procedure proceeds to the
20 ID fluctuation processing shown in Fig. 11 by skipping
the fluctuation region calculation processing and
optimum ID decision processing. More particularly, even
during pause of fluctuation and progress of fluctuation,
these two processings to be described later will not
25 executed before motor current data in the memory group
are all exchanged with new data after the commencement
of fluctuation, thereby ensuring that minimum value

- 26 -

- 1 search can be carried out under the new condition
following a change in current.

<Fluctuation Region Calculation Processing>

- The fluctuation region calculation processing
5 will be described with reference to Fig. 15. In step C-
10, a rate of change of motor current GRT with respect
to an exciting current command is calculated using the
five sets of exciting current command and motor current
data stored in the first memory group. In particular, a
10 GRT is obtained pursuant to expression shown in the
figure from a difference ΔIM between maximum and minimum
values of five motor current data pieces and a
difference ΔID between exciting current command data
pieces corresponding to the maximum and minimum values.
15 Then, the fluctuation width IDW is adjusted in
accordance with the magnitude of the thus obtained GRT
(step C-20). A rule for adjustment is such that the IDW
is made to be small when the GRT is large and conversely
the IDW is made to be large when the GRT is small.
20 Through this, the pulsating width of the motor current
caused to change with a fluctuation of the exciting
current command can be prevented from increasing or
decreasing excessively to make the pulsating width of
the motor current substantially uniform for any
25 fluctuation regions of exciting current.

Subsequently, by using the BESTID previously
described in connection with step A-30 and the

- 27 -

1 aforementioned IDW, the upper and lower limit values
IDUP and IDLW for defining the fluctuation region are
calculated (step C-30) pursuant to calculation
expressions as shown in Fig. 15 which correspond to
5 expression 4.
[Expression 4]

$$\text{IDUP} = \text{BESTID} + \text{IDW}$$

$$\text{IDLW} = \text{BESTID} - \text{IDW}$$

where limitations are imposed on IDUP and IDLW to forece
them to meet the conditions of expression 3. With the
IDUP limited to a maximum value IDMAX, a value less than
10 the IDMAX by fluctuation width IDW is determined to be a
BESTID and a lower limit value IDLW is prepared. With
the IDLW limited to a minimum value IDMIN, a value
larger than the IDMIN by fluctuation width IDW is
determined to be a BESTID and an upper limit value IDUP
15 is prepared.

In the next step C-40, one step change IDSTP
of ID is determined which is 30% of IDW. The ID
fluctuation processing is executed repetitively at the
short sampling period every long sampling period by
20 cycles which coincide with the number of of IDSTP's thus
obtained.

<Optimum ID D cision Processing>

Fig. 16 shows the contents of the optimum ID

- 28 -

1 decision processing. In step D-10, five exciting
current command data pieces ID(0) to ID(4) in the memory
group are arranged from larger one to smaller one or
vice versa and data of a medium value is selected as a
5 MIDID. If the MIDID is equal to the BESTID (step D-20),
a pre-processing for stopping fluctuation is executed
(step D-30). In the fluctuation stopping pre-
processing, the target value EXID for fluctuation is set
to the BESTID and a fluctuation pause command is issued.

10 <ID Fluctuation Processing>

The ID fluctuation processing will be
described by making reference to Fig. 17. Firstly, an
exciting current command Ild* at that time is checked
for its equality with a target value EXID (step E-10)
15 and if unequality is determined, the Ild* is so updated
as to approach the EXID (step E-60). Conversely, if
equality is determined, the procedure proceeds to step
E-30 when the issuance of a fluctuation start command
has been done but it ends when the issuance of a pause
20 command has been done. Only when it is determined in
step E-30 that the upper limit value IDUP equals a
maximum value IDMAX or the lower limit value IDLW equals
a minimum value and that data IM(4) in the memory group
is unequal to the initial value, the procedure proceeds
25 to step E-40 but if not so, the program proceeds to step
E-50 (step E-30). In other words, when the upper limit
of a fluctuation region has already reached the maximum

- 29 -

1 or the lower limit has already reached the minimum,
 indicating that the present instant is not immediately
 after the commencement of fluctuation, preparation for
 fluctuation pause is carried out in step E-40 by setting
 5 a BESTID at that time in the target value and issuing a
 fluctuation pause command. If not so, the target value
 EXID is updated in step E-50. In this case, the
 direction of fluctuation is switched by setting a lower
 limit value at that time in the EXID if the EXID at that
 10 time is an upper limit value IDUP or conversely setting
 an upper limit value at that time in the EXID if the
 EXID at that time is a lower limit value IDLW.

<Setting of Target Value upon Commencement of
 Fluctuation>

15 Fig. 18 is a flow chart showing an embodiment
 of a method of setting a target value at the time of the
 commencement of fluctuation, which setting is carried
 out in step B-40 in Fig. 14. As shown therein, when the
 upper limit value IDUP equals the maximum value IDMAX or
 20 when the equality is negated but current changes
 increasingly (motor current change integrated value
 IMSIG is positive), the lower limit value IDLW is set in
 the target value. Conversely, when the lower limit
 value IDLW equals the minimum value IDMIN or when the
 25 equality is negated but current changes decreasingly
 (motor current change integrated value is negative), the
 upper limit value IDUP is set in the target value.

- 30 -

1 Namely, when the fluctuation region is within the limit,
the fluctuation of the exciting current command is
started in a direction opposite to the direction of
change of the motor current. When the fluctuation
5 region has reached a limit value, the fluctuation is
started in a departing direction from the limit value.

<Operational Description>

Movement of the exciting current command in the
extremum search method based on the control method set
10 forth so far will now be described.

<When Motor Current Changes Linearly with Load Change>

When the motor current increases or decreases
continuously from its minimized state, the upper limit
value IDUP, BESTID, lower limit value IDLW, target value
15 EXID and exciting current command data ID represented by
a black dot mark change as shown in Fig. 19 or 20. It
is assumed in these figures that a change in motor
current due to a change in load is detected but a
pulsation of motor current concomitant with a change in
20 exciting current is not detected. Fig. 19 particularly
shows an instance where the motor current increases and
so the BESTID is the oldest one of exciting current
command data pieces for five past instants inclusive of
the present instant. Conversely, Fig. 20 particularly
25 shows an instance where the motor current decreases and

- 31 -

1 so the BESTID is exciting current command data at that
time.

Shown at (b) in Fig. 19 and at (a) in Fig. 20
are instances where changes of exciting current commands
5 are started in directions opposite to increasing and
decreasing directions of the motor current. For
example, in the case shown at (b) in Fig. 19, the
fluctuation region of the exciting current increases
gradually as the motor current increases. Then, with
10 the motor current increased on account of an increase in
load, the exciting current for minimizing the motor
current takes a larger value at that time than before
the increasing of load will be seen from Fig. 4 and
therefore the aforementioned movement of the fluctuation
15 region meets characteristics shown in Fig. 4. Likewise,
Fig. 20 shows at (a) movement of the fluctuation region
of exciting current command which decreases as the motor
current decreases and this movement meets the characte-
ristics of Fig. 4.

20 On the other hand, in instances shown at (a)
in Fig. 19 and at (b) in Fig. 20, the exciting current
command starts fluctuating in the same direction as the
changing direction of the motor current, that is, with
the motor current increased, the exciting current
25 command starts fluctuating in its increasing direction
and with the motor current decreased, the exciting
current command starts fluctuating in its decreasing
direction. In these instances, the fluctuation region

- 32 -

1 of the exciting current command moves in the opposite
direction to the changing direction of the motor
current. The fluctuation start method in these
instances is effective to meet the case where, in
5 contrast to the Fig. 4 characteristics and the minimiza-
tion of motor current of induction motor exemplified in
the present embodiment, the value of the manipulated
variable at which the controlled variable takes an
extremum decreases as the disturbance increases.

10 <When Load Changes Stepwise>

The operation in an instance where the motor
current changes stepwise will now be described by
referring first to Fig. 1.

It is assumed in Fig. 1 that the load
15 increases at timing ① and the motor current increases
sympathetically. With the motor current increased, when
a motor current change integrated value IMSIG exceeds a
fluctuation start allowable value IMLV and this is
detected at time point ② (step B-20), a fluctuation
20 start command as shown at (2) in Fig. 1 is issued (step
B-40). Then, for the increasing current, the target
value EXID is set to a lower limit value IDLW and the
exciting current command starts fluctuating in its
decreasing direction (step B-44 in Fig. 18). Since at
25 time point ③ the varying exciting current command
coincides with the target value, the target value EXID
is changed to an upper limit value IDUP to cause the

- 33 -

1 exciting current to fluctuate in its increasing direc-
tion (step E-50). Before time point ④ at which data
pieces in the memory group 12 are all updated to new
data pieces, the fluctuation region calculation proces-
5 sing and optimum ID decision processing are not carried
out and so the upper and lower limit values before
fluctuation are maintained (step B-60). It is to be
noted that a black dot mark shown at (2) in Fig. 1
represents a timing that motor current data IM(0) is
10 stored in the memory group 12 and a black dot mark shown
at (4) in Fig. 1 represent a timing for storage of
exciting current command data ID(0) in the memory
group 12.

After time point ④, a series of processings
15 are executed in which an exciting current command data
piece corresponding to a minimum of five motor current
data pieces is determined to be a BESTID (step A-30), an
upper limit value IDUP and a lower limit value IDLW
which define a fluctuation region centered on the thus
20 determined BESTID are calculated (step C-30) and the
BESTID is decided as to whether to be an optimum value
(step D-20). At time points ⑤ and ⑥, the target value
EXID is changed.

It is now assumed that a minimum value of the
25 motor current can be searched out at time point ⑦.
Namely, when a data piece taking a medium value of the
five exciting current command data pieces ID(0) to ID(4)
assumptively equals a BESTID (ID(2) in the illustrated

- 34 -

1 example), a fluctuation pause command is issued as shown
at (3) in Fig. 1 and the target value EXID is set to the
BESTID, i.e., ID(2), thus completing the minimum value
search. Thereafter, the exciting current command at
5 that time is changed to the optimum exciting current
command. More specifically, on the assumption that the
BESTID at that time is a first exciting current command
and the exciting current command delivered at that time
(corresponding to ID(0) in the illustrated example) is a
10 second exciting current command, the first command is
smaller than the second command and therefore the
exciting current command is changed in its decreasing
direction.

An instance shown in Fig. 21 will now be
15 described. This differs from the Fig. 1 example in that
the upper limit value IDUP equals a maximum value IDMAX
and consequently the exciting current fluctuation region
is limited.

In the procedure in which the load changes and
20 the minimum value is searched by fluctuating the excit-
ing current command, at time point ⑤ shown in Fig. 21,
an upper limit value IDUP prepared on the basis of a
BESTID at that time tends to exceed a maximum value
IDMAX. In this case, as has been explained in connec-
25 tion with step C-30 in Fig. 15, the upper limit value
IDUP behaves as the maximum value IDMAX, so that a value
less than IDMAX by a fluctuation width IDW is determined
to be a BESTID and a value less than the BESTID by the

- 35 -

1 fluctuation width IDW is determined to be a lower limit
value IDLW. Then, as shown in Fig. 21, the target value
EXID is switched at time point ⑤ to a lower limit value
IDLW at that time to change the direction of fluctuation
5 and subsequently, at time point ⑥ that coincidence with
the lower limit value occurs, the target value EXID is
changed to an upper limit value IDUP at that time, i.e.,
the maximum value IDMAX.

Assumptively, at time point ⑦, the varying
10 exciting current command coincides with the target value
which is the maximum value. At that time, the proces-
sing of step E-40 in Fig. 17 is executed to issue a
fluctuation pause command as shown at (3) in Fig. 21 and
a BESTID at that time is set to a target value EXID,
15 thus completing the minimum value search processing.
Thereafter, the processing is executed in which the
exciting current is changed from the exciting current
command at that time, i.e., the maximum value to the
BESTID. More specifically, on the assumption that
20 exciting current command data ID(3) corresponding to a
minimum motor current data piece at time point ⑦ is a
first exciting current command and the exciting current
command at that time which is the maximum value IDMAX is
a second exciting current command, the first exciting
25 current command is smaller than the second exciting
current command and therefore the exciting current
command is changed in its decreasing direction.

- 36 -

1 In the above operational example shown in Fig.
21, the upper limit value IDUP behaves as the maximum
value IDMAX to limit the exciting current fluctuation
region but conversely, with the lower limit value IDLW
5 behaving as the minimum value IDMIN to limit the excit-
ing current fluctuation region, when the exciting
current command fluctuating toward the lower limit value
coincides with the lower limit value, i.e., the minimum
value, the movement of the fluctuation region is stopped
10 and the target value is set to a BESTID at that time.
More specifically, on the assumption that the BESTID at
that time is a first exciting current command and the
exciting current command at that time, i.e., the maximum
value is a second exciting current command, the first
15 exciting current command is larger than the second
exciting current command and therefore the exciting
current command is changed in its increasing direction.

<Resumption of Fluctuation from Fluctuation Region
Limited State>

20 With reference to Fig. 22, movement of the
exciting current command will be described by referring
to an instance where from the state that the fluctuation
region is limited as described with reference to Fig.
21, that is, the state that the upper limit value IDUP
25 equals the maximum value IDMAX or conversely the lower
limit value IDLW equals the minimum value IDMIN, the
load changes and the minimum value search resumes.

- 37 -

1 An instance shown at (a) in Fig. 22 is
directed to the former case and since the upper limit
value IDUP is the maximum value IDMAX, the target value
EXID is set to the lower limit value IDLW after a change
5 in motor current is recognized and the exciting current
command starts fluctuating in a direction for departure
from the maximum value IDMAX (step B-44 in Fig. 18). On
the other hand, an instance shown at (b) in Fig. 22 is
directed to the latter case and since the lower limit
10 IDLW is the minimum value IDMIN, the target value EXID
is set to the upper limit value IDUP and the exciting
current command starts fluctuating in a direction for
departure from the minimum value IDMIN (step B-45 in
Fig. 18).

15 In accordance with the resumption method
described as above, the exciting current command will
not reach the limit value rapidly and stopping of the
fluctuation can be prevented, thus ensuring that the
exciting current can be fluctuated within a wide range
20 defined by the upper and lower limit values to permit
correct minimum value search.

<Another Embodiment of Changing Method for Target Value>

 In the changing method for target value EXID
described in the foregoing embodiment, as shown in Fig.
25 17, only when the varying exciting current command Ild*
coincides with the target value EXID, the upper limit
value IDUP or the lower limit value IDLW is changed.

- 38 -

1 Contrarily, in a method described in this embodiment,
each time that the upper limit value or the lower limit
value is updated, the target value is changed to the
latest upper limit value or lower limit value. To this
5 end, the ID fluctuation processing shown in Fig. 17 is
headed with contents of processing as shown in Fig. 23.
More specifically, if the target value at that time has
been an upper limit value, a new target value is set to
an upper limit value at that time but if the target
10 value at that time has been a lower limit value, a new
target value is set to a lower limit value at that time.

Fig. 24 is a diagram to explain the above
target value changing method and it corresponds to Fig.
19. Particularly shown in Fig. 24 is the movement of
15 fluctuation region occurring when the motor current
increases continuously and the exciting current starts
fluctuating. It is also assumed in Fig. 24 that a
change in motor current concomitant with the exciting
current fluctuation cannot be detected. When the
20 fluctuation of exciting current command starts in its
increasing direction as shown at (1) in Fig. 24, the
center of the fluctuation region is raised from the
initial state so as to be maintained at the raised state
and the exciting current command changes repetitively to
25 go above and below the raised state; and when the
fluctuation of exciting current command starts in its
decreasing direction as shown at (2) in Fig. 24, the
center of the fluctuation region is lowered from the

- 39 -

1 initial state so as to be maintained at the lowered
state and the exciting current command changes
repetitively to go above and below the lowered state.
Thus, in contrast to the foregoing example, the
5 fluctuation region does not increase as the motor
current increases.

<Movement of Winding Current>

In the embodiments of the extremum search
method described previously, winding current flowing in
10 the winding of the induction motor moves as shown in
Fig. 25. The inverter output voltage and winding
current change when the load increases and decreases
stepwise as shown at (1) in Fig. 25 and in the figure,
an envelope (locus of peak value) of the change of the
15 inverter output voltage is shown at (2) in Fig. 25 and
that of the winding current is shown at (3) in Fig. 25.
More particularly, as the load changes from a minimum
state thereof to cause the winding current to change,
the output voltage is so changed that the winding
20 current takes a new state and pulsates around the new
state by assuming averaged values of pulsation which are
directed to a minimum.

<Effects of Embodiment of the Invention>

Specific effects brought about by the
25 embodiment of the invention are graphically shown in
Fig. 26, where abscissa represents load torque and

- 40 -

1 ordinate represents inverter output voltage, winding
current and total efficiency of the inverter and motor
which are respectively obtained with and without the
minimization control.

5 As will be seen from the figure, without the
minimization control, the inverter output voltage is
constant regardless of the load, the winding current is
large and the efficiency is degraded. But by practicing
the control for minimization of current of the induction
10 motor according to the invention, the efficiency can be
improved and the winding current can be lowered for the
same load, thereby making it possible to reduce the
inverter capacity and suppress the temperature rise.
Further, the temperature rise in the compressor loaded
15 on the induction motor can also be suppressed to improve
the efficiency of the compressor. As will be noted,
values of the efficiency and winding current in the
absence of the minimization control are the same as
those of the efficiency and winding current in the
20 presence of the minimization control at a certain load
state. This is because even in the absence of the
minimization control, the winding current is minimized
only at that load state. Therefore, when the minimiza-
tion control is applied, its effect is highlighted in
25 proportion to the distance of the load torque from that
load state.

Although the foregoing embodiment has been
described as being directed to the method for

- 41 -

1 minimization of current of the induction motor adapted
to drive such a load as the compressor of air
conditioner and refrigerator, the present invention is
not limited thereto and may be applied to any control
5 system in which the extremum of the controlled variable
with respect to the manipulated variable is changed by
the disturbance as shown in Fig. 2. For example, the
invention may also be applied to an inverter apparatus
of an induction motor adapted to drive a fan or a pump.

10 <Another Embodiment of the Invention>

Another embodiment of the invention is shown
in Fig. 27. In the foregoing embodiment of Fig. 5, the
winding current of the AC motor is detected and used as
the controlled variable but differently, in the present
15 embodiment a DC current i_{dc} is detected by a current
detector/amplifier 20 and an output signal IDC is used
as the controlled variable. Currents as viewed from the
input and output of the inverter are of DC and AC to
differ from each other but the magnitude of current in
20 terms of an average value is substantially the same for
both the currents. Accordingly, the present embodiment
directed to detection of the controlled variable on the
DC side of the inverter is advantageous over the
foregoing embodiment in that only one current detector
25 suffices and rectifying operation means for determining
an average value of current is dispensed with, thus
simplifying the construction and decreasing the control

- 42 -

1 operation processing time to permit high-speed response,
to advantage.

As described above, the present invention
attains the following meritorious effects.

5 (1) Even when the disturbance or the motor load is
changing, the minimum value of the motor current stand-
ing for the controlled variable can be searched without
recognizing the change to obtain an inverter output
voltage standing for the manipulated variable which
10 corresponds to the minimum value.

(2) The motor current can be minimized without
being affected by noise components and ripples contained
in the detected value of the motor current standing for
the controlled variable.

15 (3) By virtue of the above advantages, the minimi-
zation of the motor current according to the invention
can be free from not only local extrema caused by noise
or varying disturbance but also the divergence pheno-
menon that the search for extrema is done in vain to
20 cause the manipulated variable to increase or conversely
decrease excessively, thereby ensuring stable operation
and very high practicality.

- 43 -

CLAIMS:

1. A method of controlling an inverter in which the inverter receiving direct current and delivering alternating current drives an AC motor controllably by using its AC output voltage as a manipulated variable, wherein when motor current increases or decreases starting from a running state at which input current to said motor is constant, said manipulated variable is changed at a running state subject to an increased or decreased motor current to pulsate the motor current and is sequentially determined in a direction in which an average value of the pulsating motor current decreases gradually.
2. An inverter control method according to Claim 1 wherein said manipulated variable is a voltage command value which commands said inverter to deliver AC voltage.
3. An inverter control method according to Claim 1 wherein said manipulated variable is an exciting current component of AC motor current which generates a voltage command value for commanding said inverter to deliver AC voltage.
4. An inverter control method according to Claim 1 wherein a fluctuation region is set up to permit said manipulated variable to fluctuate within a range defined by predetermined upper and lower limit values, and said fluctuation region is moved as the time elapses in a direction in which at least one of a change width and a

- 44 -

change rate of the input current or output current of said inverter standing for a controlled variable is decreased.

5. An inverter control method according to Claim 4 wherein for said fluctuation region, a first target value and a second target value are set which are defined by said upper and lower limit values, respectively, said manipulated variable is changed to approach one of said target values and when said manipulated variable tends to exceed said one target value, the other target value is set to an upper limit value or a lower limit value at that time, said manipulated variable is changed to approach the thus set target value and said two target values are moved as the time elapses in a direction in which at least one of a change width and a change rate of the controlled variable decreases gradually.

6. An inverter control method according to Claim 4 wherein for movement of said fluctuation region, there are provided a plurality of sets of paired data pieces of manipulated variables and corresponding controlled variables which are obtained before movement, a manipulated variable of a set having a corresponding controlled variable which is an extremum is selected from said plurality of set, and the fluctuation region of manipulated variable is decided sequentially such that the selected manipulated variable falls within the fluctuation region.

- 45 -

7. An inverter control method according to Claim 4 wherein the fluctuation width of said fluctuation region is so selected as to be small when the absolute value of a rate of change of said controlled variable relative to said manipulated variable is large but to be large when the absolute value of the change rate is small.

8. An inverter control method according to Claim 4 wherein said manipulated variable and the corresponding controlled variable are put together to set up a set, at least three sets are stored in a memory group, a memory of one set of the manipulated variable and controlled variable is updated every predetermined period in said memory group, a manipulated variable of a set having a corresponding controlled variable which is an extremum is selected from said memory group, said fluctuation region is so reset that said selected manipulated variable may fall within said fluctuation region, and a next value of the manipulated variable is set in a direction in which said selected manipulated variable approaches an upper limit value or a lower limit value of said fluctuation region.

9. An inverter control method according to Claim 8 wherein said predetermined period is shared by first and second two modes, the manipulated variable is changed stepwise at a period shorter than said predetermined period in said first mode but is made to be constant in said second mode, and at least one set of

- 46 -

the manipulated variable and controlled variable of memory group is stored in said memory group before said second mode shifts to the first mode of the next cycle.

10. An inverter control method according to Claim 8 wherein a plurality of manipulated variables are arranged from smaller one to larger one or vice versa in said memory group, and when a controlled variable corresponding to a manipulated variable of medium value is the smallest of all the controlled variables in said memory group, the movement of the fluctuation region is stopped.

11. An inverter control method according to Claim 8 wherein at the commencement of changing said manipulated variable during the pause of movement of said fluctuation region, said manipulated variable is permitted to start changing when a change amount of said controlled variable exceeds a predetermined allowable value, whereby when the change amount increases, said manipulated variable is changed in its decreasing direction but in its increasing direction when the change amount decreases.

12. An inverter control method according to Claim 8 wherein a maximum value and a minimum value of said manipulated variable are set up, whereby when the upper limit value of said fluctuation region tends to exceed said maximum value or when the lower limit value of said fluctuation region tends to exceed said minimum value, the upper limit value of said fluctuation region is set

- 47 -

to said maximum value or the lower limit value of said fluctuation region is set to said minimum value, and when the varying manipulated variable reaches said upper limit value or said lower limit value, a manipulated variable corresponding to a controlled variable in said memory group which is an extremum at that time is selected and determined and the movement of said fluctuation region is stopped.

13. An inverter control method according to Claim 12 wherein at the commencement of changing said manipulated variable during the pause of movement of said fluctuation region, said manipulated variable is permitted to start changing when a change amount of said controlled variable exceeds a predetermined allowable value, whereby when an upper limit value of fluctuation region of said manipulated variable at that time is said maximum value of manipulated variable, said manipulated variable is so set as to change in its decreasing direction but when a lower limit value of fluctuation region of said manipulated variable at that time is said minimum value of manipulated variable, said manipulated variable is so set as to change in its increasing direction.

14. An inverter control method according to Claim 4 wherein the contents of one control processing is defined by changing of said manipulated variable and detection of a controlled variable corresponding to a manipulated variable after changing, at least three

- 48 -

control processings are executed to provide resulting sets of manipulated variable and controlled variable which are of the same number as that of the executed control processings, a manipulated variable of a set having a corresponding controlled variable which is an extremum and a manipulated variable which has already been delivered at the latest time point are selected as a first manipulated variable and a second manipulated variable, respectively, from said sets, and the second manipulated variable is so set as to change in the succeeding control processing in its increasing direction when said first manipulated variable is larger than said second manipulated variable but in its decreasing direction when said first manipulated variable is smaller than said second manipulated variable.

15. An apparatus of controlling an inverter which converts direct current into alternating current and controllably drives an AC motor, comprising:

means for generating a command value for AC output voltage of said inverter;

means for controlling said inverter on the basis of said output voltage command value;

means for detecting AC output current of said inverter;

means for converting the magnitude of said AC output current into a DC variable;

- 49 -

at least three memory elements for storing paired data pieces of said output voltage command value and said DC variable corresponding thereto every predetermined time interval;

means for fetching at least three data pieces of said DC variable from said memory elements and calculating a minimum value from the fetched data pieces; and

means for fetching an output voltage command value corresponding to said minimum value and data pieces representative of the other output voltage command values to compare them and changing the output voltage command value at said inverter AC output voltage command value generating means in its increasing direction when said output voltage command value corresponding to said minimum value is larger than the data pieces representative of the other output voltage command values but conversely in its decreasing direction when said output voltage command value corresponding to said minimum value is smaller than said data pieces representative of the other output voltage command values.

16. An apparatus of controlling an inverter which converts direct current into alternating current and controllably drives an AC motor, comprising:

means for generating an exciting current command value for said AC motor;

- 50 -

means for calculating a command for AC output voltage of said inverter on the basis of said exciting current command value;

means for controlling said inverter on the basis of said output voltage command value;

means for detecting AC output current of said inverter;

means for converting the magnitude of said AC output current into a DC variable;

at least three memory elements for storing paired data pieces of said exciting current command value and said DC variable corresponding thereto every predetermined time interval;

means for fetching at least three data pieces of said DC variable from said memory elements and calculating a minimum value from the fetched data pieces; and

means for fetching an exciting current command value corresponding to said minimum value and data pieces representative of the other exciting current command values to compare them and changing the exciting current command value at said exciting current command value generating means in its increasing direction when said exciting current command value corresponding to said minimum value is larger than the data pieces representative of the other exciting current command values but conversely in its decreasing direction when said exciting current command value corresponding to

- 51 -

said minimum value is smaller than said data pieces representative of the other exciting current command values.

17. An apparatus of controlling an inverter which converts direct current into alternating current and controllably drives an AC motor, comprising:

means for generating a command value for AC output voltage of said inverter;

means for controlling said inverter on the basis of said output voltage command value;

means for detecting DC input current of said inverter; at least three memory elements for storing paired data pieces of said output voltage command value and a DC current detected value corresponding thereto every predetermined time interval;

means for fetching at least three data pieces of said DC current detected value from said memory elements and calculating a minimum value from the fetched data pieces; and

means for fetching an output voltage command value corresponding to said minimum value and data pieces representative of the other output voltage command values to compare them and changing the output voltage command value at said inverter AC output voltage command value generating means in its increasing direction when said output voltage command value corresponding to said minimum value is larger than the data pieces representative of the other output voltage

- 52 -

command values but conversely in its decreasing direction when said output voltage command value corresponding to said minimum value is smaller than said data pieces representative of the other output voltage command values.

18. An apparatus of controlling an inverter which converts direct current into alternating current and controllably drives an AC motor, comprising:

means for generating an exciting current command value for said AC motor;

means for calculating a command for AC output voltage of said inverter on the basis of said exciting current command value;

means for controlling said inverter on the basis of said output voltage command value;

means for detecting DC input current of said inverter; at least three memory elements for storing paired data pieces of said exciting current command value and a DC current detected value corresponding thereto every predetermined time interval;

means for fetching at least three data pieces of said DC current detected value from said memory elements and calculating a minimum value from the fetched data pieces; and

means for fetching an exciting current command value corresponding to said minimum value and data pieces representative of the other output voltage command values to compare them and changing the exciting

- 53 -

current command value at said exciting current command value generating means in its increasing direction when said exciting current command value corresponding to said minimum value is larger than the data pieces representative of the other exciting current command values but conversely in its decreasing direction when said exciting current command value corresponding to said minimum value is smaller than said data pieces representative of the other exciting current command values.

19. An inverter control apparatus according to any one of Claims 15 to 18, wherein said apparatus is adapted to control an inverter which drives, at varying speeds, an induction motor for drive of a compressor.

20. An inverter control apparatus according to any one of Claims 15 to 18, wherein said apparatus is adapted to control an inverter which drives, at varying speeds, an induction motor for drive of a fan or pump.

21. A method of controlling an inverter substantially as any one herein described with reference to Figs. 1 to 27 of the accompanying drawings.

22. An apparatus for controlling an inverter substantially as herein described with reference to and as illustrated in Figs. 1 to 22, or Figs. 23 to 26, or Fig. 27 of the accompanying drawings.

- 54 -

Patents Act 1977**Examiner's report to the Comptroller under
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Relevant Technical fields(i) UK CI (Edition K) H2F (FDAC, FDACS, FDACX)
H2J (JSVP, JSV, JSVF, JSAX)

(ii) Int CL (Edition 5) H02M, H02P

Search Examiner

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Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

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Documents considered relevant following a search in respect of claims

1-14 AND 21

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2229870 A (HITACHI) see 8, 10 figure 1	1-3
X	GB 2093288 A (HITACHI) see 13, 20 figures 1, 10 and 11 and especially page 7, lines 16-45	1-3
X	EP 0293915 A2 (HITACHI) see 10 figure 1	1-3
X	EP 0241920 A2 (HITACHI) see 21, 51, 52 figure 1	1-3
X	EP 0151418 A1 (HITACHI) see 6, 8, 17-20 figure 1	1-3

-55-

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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